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# Metal Progress

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# Some Notes on

# Armor Plate

# for Ships and Tanks

IN VIEW of the very great interest in the subject of armor, and the difficulty of getting information about modern manufacturing and heat treatment methods that the censor thinks might be printed, the Editor asked and received permission from the United States Naval Institute to reproduce these portions about naval armor from "Naval Ordnance" (1939 Edition) used as a text book at Annapolis:

## Naval Armor

THE FIRST PUBLICLY recorded proposal to sheath the hulls of naval vessels with a metal shield was made by Sir William Congreve in *The Times* in London on February 20, 1805. A similar proposal was later made by John Stevens, of Hoboken, N. J., in 1812. Nothing came of these proposals, but in spite of such lack of encouragement, John Stevens and his sons determined the laws of penetration of iron plates by cannon balls and the maximum thickness of iron plate necessary to defeat any then known gun. In 1842, Robert L. Stevens, one of John Stevens' sons, presented the results of these experiments, and a new design of a floating battery, to a committee of Congress, and this resulted in the armored ship Stevens Battery (1854).

The only metal, practicable and available in suitable quantity at this period, was iron, wrought or cast, and all experiments showed that the wrought iron was far superior, pound for pound, in defeating projectiles. These first ironclads were therefore protected by wrought iron plates 4 to 5 in. thick, backed by 36 in. of wood timbers.

Costly experiments on laminated iron plates, with laminations in contact or with wooden timbers between, showed that single plates always gave greater resistance per pound of protection. (American ironclads, during the Civil War, used laminated plates because facilities for making thick plates were lacking.) Proposals were early made to use cast or chilled iron plates for the outer lamination, to weld a 1-in. blister steel plate to heavier wrought iron plates, or to carburize one surface of the wrought iron, but all these proposals failed either because of the inherent inferiority of a laminated plate or because the existing art of metallurgy was not then equal to the task.

In 1876 gun power and projectile quality had so increased that about 22 in. of iron was necessary to defeat a projectile from the heaviest cannon. In that year trials showed that a 22-in. forged openhearth oil-quenched steel plate manufactured by Schneider et Cie. in Creusot, France, completely outclassed all its iron competitors. This steel plate was more prone to break up and this difficulty led to the next real development, which logically resulted from efforts to combine the hardness of steel in the face of a plate with the toughness of iron in its back.

Thus resulted the compound type of armor, the two principal examples of which were the Wilson-Cammel compound plate, in which an openhearth steel face was cast on top of a hot wrought iron back plate, and the Ellis-Brown compound plate in which a steel face plate was cemented to an iron back plate by pouring molten bessemer steel between them. In both these processes, which were English, the plates were rolled after compounding.

Great competition and controversy existed as to the relative quality of all-steel and compound armor. The all-steel Schneider armor was a simple steel of about 0.30 to 0.40% carbon, while the steel face of the compound armor contained between 0.50 and 0.60% carbon. These two classes

of armor, their comparative value depending largely on the skill with which they were made, were approximately 25% superior to their wrought iron predecessor — that is to say, a 10-in. compound and a 12.6-in. iron plate would resist the same striking energy.

*Nickel Steel Armor* — The next step in advance occurred about 1889 when Schneider introduced nickel into all-steel armor. It completely eliminated compound armor, 4% nickel greatly increasing the strength and toughness. At about this same time oil and water quenching were successfully applied to armor plates by Schneider. After forging under a hammer and annealing, the plate was heated to a quenching heat and its face was dipped for a short depth in oil until the whole plate was cold, this being followed by a low temperature tempering.

These improvements resulted in a further increase of about 5% in the resistance of armor; that is to say, a heat treated 10-in. nickel steel plate equaled about 13 in. of iron.

At about this time both the Bethlehem and the Carnegie steel companies started manufacturing in America. Armor for the battleship Maine and others of that period analyzed 0.20% carbon, 0.75% manganese and 3.25% nickel.

*Harvey Armor* — In 1890 the next great improvement was first applied to armor when a Creusot 10.5-in. steel plate was "Harveyized" at the Washington Navy Yard. This process, the invention of H. A. Harvey of Newark, N. J., consisted in carburizing the face of a steel plate by heating it for two to three weeks in intimate contact with a bone charcoal or other carbonaceous compound. This gave a "case" about 1 in. deep, with maximum of 1.0 to 1.1% carbon at the surface. The entire plate was then oil quenched from a rather high temperature and water quenched from a lower temperature, the result being a hard face (a quenched high carbon steel) and a tough back. Improved quenching methods were patented by the Englishman Tressider, who chilled the carburized face by a dense spray of fine streams of water under high pressure. We now had the nickel steel, cemented, oil-tempered, water-sprayed, face-hardened armor known as Harveyized or Harvey armor.

A typical chemical analysis shows about 0.20% carbon, manganese about 0.60% and nickel 3.25 to 3.50%. Further grain refining and toughening was had by a 10% reduction by forging, at a rather low temperature, after the carburizing operation ("double forging"). All these improvements amounted to another 15 to 20% increase.[1]

[1]Editor's Footnotes: 13 in. of Harvey armor equaled about 20.1 in. of wrought iron.

## *Manufacture of Krupp Cemented Armor*

*Krupp Armor* — The problem of adding chromium to large steel ingots was solved by Krupp about 1893, who then made nickel-chromium armor and carburized it with hot illuminating gas. (Gaseous cementation has been gradually superseded by solid hydrocarbons.)

At about the same time Krupp developed a process of deepening the hardening on one side of a cemented steel plate. To do this, the plate was imbedded in clay or loam, with the cemented side exposed, and then the exposed face was subjected to a very hot and quick heat. As the heat penetrated gradually, the exposed face became much hotter than the back, thus permitting "*decremental hardening*" by water spraying. While the plate is heated from the carburized side only, the transition temperature was allowed to sink between 30 and 40% of the thickness, whereupon the plate was hurriedly withdrawn from the furnace, put in a spraying pit and subjected to a powerful spray of water on the superheated side (and later on both sides, to prevent, as much as possible, the warping which a spray on but one side would produce).

Such "decremental face hardening" hardens the outer third of the thickness, leaving the backing in its original tough condition.[2] It is entirely aside from the carburized layer, which in a 10-in. armor may be not much more than 1¼ in. deep, whereas the hard or chilled zone goes to 4 or 4½ in. deep. This process of decremental face hardening is the final heating operation, preliminary heat treatment having refined the grain.

The success of the Krupp process was immediate, and all armor manufacturers soon adopted it. In all plates thicker than about 5 in., the Krupp armor was about 15% more efficient than its immediate predecessor, 11.9 in. of Krupp being about equal to 13 in. of Harveyized armor. American vessels first used it in 1900, and most of the side armor made for the past 25 years has been Krupp cemented armor.

During the past 15 years, various slight improvements have been made in the technique of manufacture; and it is, as now made, possibly 10% better, ballistically, than it was at first.[3]

Carbon being the principal hardening element, the natural tendency is to carry it as high as possible. The higher the carbon, however, the

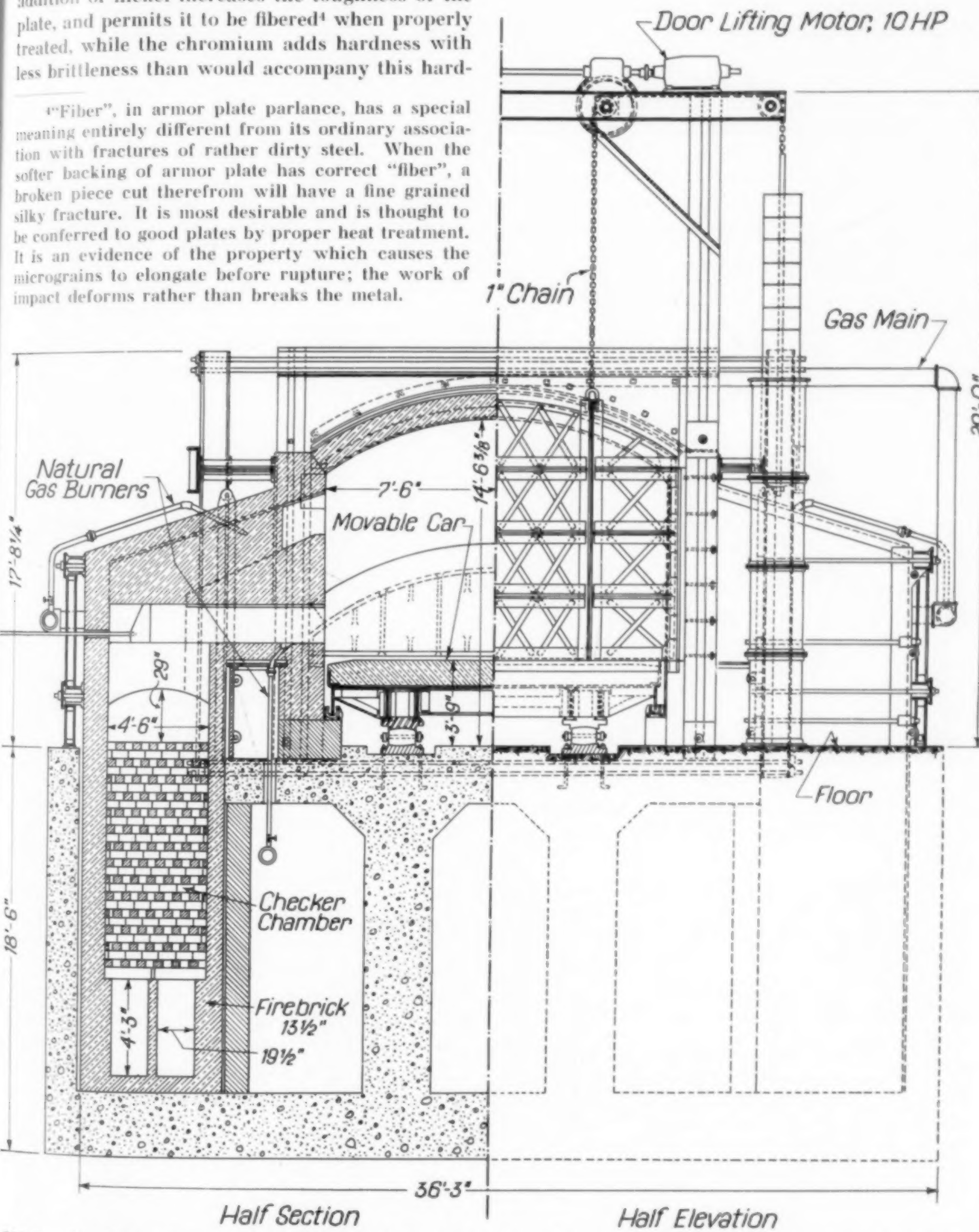
[2]Today's counterpart of this operation is flame hardening.

[3]On this basis 10 in. of Krupp cemented armor would be equivalent to about double the thickness of wrought iron (although direct comparison in this manner is probably inadmissible, for the two materials are in different categories of merit).

more difficult becomes manufacture, tears appear in the forging, "fibering" the plate becomes more difficult, and the plate becomes brittle, making it liable to cracking and excessive spalling (detaching of surface fragments) on ballistic test. The addition of nickel increases the toughness of the plate, and permits it to be fibered[4] when properly treated, while the chromium adds hardness with less brittleness than would accompany this hardness if produced solely by carbon. The chromium also facilitates the decremental water hardening.

A typical chemical analysis of a modern Krupp cemented (K.C.) plate is as follows: Car-

[4] "Fiber", in armor plate parlance, has a special meaning entirely different from its ordinary association with fractures of rather dirty steel. When the softer backing of armor plate has correct "fiber", a broken piece cut therefrom will have a fine grained silky fracture. It is most desirable and is thought to be conferred to good plates by proper heat treatment. It is an evidence of the property which causes the micrograins to elongate before rupture; the work of impact deforms rather than breaks the metal.




*700-Ton Car Bottom Furnaces for Heating or Carburizing Armor Plate at U. S. Naval Ordnance Plant. Lengths 36 to 50 ft. (From paper by R. M. Freeman before 1920 meeting of American Society of Mechanical Engineers)*

bon 0.35%, nickel 3.90, chromium 2.00, manganese 0.35, silicon 0.07, phosphorus 0.025 and sulphur 0.020%. (In this connection it is interesting to note that when K.C. armor was first introduced into America, the plates ran about 0.27% carbon, 3.75% nickel, and 1.75% chromium.)

A modern process of manufacture may be briefly summarized as follows:

1. The charge of pig iron and ore or pig iron and selected scrap is melted in a basic openhearth furnace and is then poured into an iron or sand mold. The dimensions of an ingot are varied to suit conditions; for instance, an ingot for a three-gun turret port plate is about 42x150x250 in. and weighs about 425,000 lb., while one for a belt plate is about 26x132x200 in. and weighs about 200,000 lb.[5]

2. The ingot, while still hot, is stripped from the mold and put into a reheating furnace.

3. The ingot is then forged under a hydraulic press to within about 15% of the final thickness. The forging reduces the ingot to about one-third of its previous thickness. Segregated impurities in the upper portion are discarded.

4. The forging — now about two-thirds the weight of the ingot — is annealed to produce a partially "fibrous" condition, and furnace cooled to prevent cracking in cooling and to eliminate the strains due to forging.

5. It is then carburized by placing flat in a car bottom type of furnace. The side to be cemented is up. A brick wall is built on an angle iron shelf, tack welded to the edges to retain a thick layer of carburizing compound. Then another plate of equivalent size is put face down, and all joints luted with clay. Sometimes two or more "sandwiches" of this sort are heated in a single furnace load. The heat varies from 10 to 14 days, depending on the mass of steel in the furnace and the depth it is to be carburized.[6]

6. Reheating, reforging nearly to the final thickness, and annealing follow.

[5]Such large ingots contain unusually large sink heads and are poured from two or more furnaces. They cool slowly and hence are likely to be coarse crystalline and tender to forge. Sand molds intensify these troubles. The steel is not unusually clean, emulsified inclusions being useful in seeding the primary crystallization and in promoting fiber.

[6]For some notes on the carburization of armor plate, see W. I. McInerney, "Carburizing Heavy Sections", *Transactions* American Society for Steel Treating, Vol. II, p. 237 (1921). Describing methods used at United States Naval Ordnance Plant, he notes that plates are preheated to 1500° F. before solid carburizer is spread on. Measurable increase in carbon content to a depth of 2 in. is secured in 10 days at 1875° F. At the end the plate is cooled to 1500° F., removed, the spent carburizer dumped, replaced with a layer of buckwheat coal and covered with dry yellow clay, and reheated for final forging.

7. Several heat treatments may follow to develop the physical properties in the fiber.[7]

8. The forging is next machined to the rough dimensions.

9. It is then reheated and formed to shape.

10. The front face is then heated above the critical temperature, depending upon the depth of chill desired, and hardened by spraying.

11. After low reheating (tempering) the curvature of the plate is rectified.

12. The edges and back of the plate are machined[8] to the finished dimensions.

*Non-Cemented Armor* — It is quite apparent that a plate may be hardened, decrementally, without prior cementation, and this in fact was done by both Bethlehem and Midvale Steel Co. The process is especially adaptable to the thinner varieties of plate, for the carburized face is tender during all steps of fabrication. It is known as Krupp non-cemented (K.N.C.) armor. In structure, it differs appreciably from K.C. armor. The chill is generally harder and somewhat deeper; and there is a further difference in chemical composition. K.N.C. armor is fully equal, ballistically, to K.C. armor, and can in fact be made of superior ballistic resistance, but it has an unfortunate tendency to spalling, both on projectile impact and from internal strain. It was this tendency to spalling which led to the abandonment of the process after a few years of use.

## *Ballistic Tests*

The above armor, K.C. or K.N.C., is termed "Class A" armor by the American Navy. Its manufacture is carefully watched, and after hardening coupons are broken off opposite corners for examination of the internal structure. One plate is selected from each "group" of 600 to 1200 tons and tested ballistically. At the proving ground it is supported in a very strong plate-butt so all movement is prevented during impact. Two shots at specified angle, striking velocity and energy are made to determine whether the plate is up to standard. Once this is established, and the group's acceptability settled, the plate is attacked by additional shots to determine its precise ballistic limit. By carefully investigating the best plates the general standards may be raised.[9]

[7]Equipment for spray quenching and immersion quenching must be on the same grand scale as the handling devices for 150-ton forgings.

[8]Conveniently done by oxy-acetylene flame.

[9]If the test plate fails, the manufacturer may reheat the other plates in the group, and the testing routine is repeated. If the second plate fails, the group is rejected. Many contracts include a bonus for high ballistic tests — a greater incentive for improvement than metallurgical research by the Navy.

### *Class B Armor*

It early became apparent that face-hardened armor was less effective against oblique impacts than was an equal weight of homogeneous armor. It is apparent that to resist a glancing blow a hard face is unnecessary; what is desired is a combination of the highest strength and ductility in order that the projectile may be gradually deflected. In other words, against oblique attack we permit the armor to *give* under the blow, thereby spreading the effect, while the projectile slides along the trough it creates, thus further spreading the effect, and finally it is completely deflected.

Such armor is now called "Class B Armor" in the U. S. Navy, but it is also referred to as deck armor, horizontal armor, and sometimes as special-treatment steel.

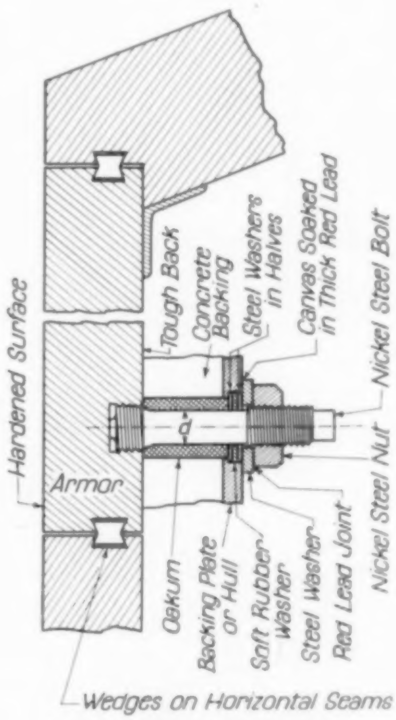
Nickel steel continued to be used for horizontal armor until about 1909 when Carnegie Steel Co. made some of the newly developed nickel-chromium-vanadium alloy steel. The change in composition and increased metallurgical skill enabled its resisting powers to be considerably increased. In that year the ballistic testing of protective decks and turret tops began. About 1914 the use of vanadium was discontinued. At present, a nickel-chromium steel of approximately the same chemical composition as Class A armor is used, that is, carbon about 0.30%, nickel about 3.85%, and chromium about 1.85%, nominal composition.

Class B armor, when less than 4 in. thick, is rolled instead of being forged, but above that thickness it is forged, as rolling thick plates is believed to work the plate less uniformly than forging, a condition which would tend to reduce ballistic resistance. The treatment is quite different from that of K.C. armor, for the desideratum is to secure great strength and ductility. Thus tensile test specimens frequently show an ultimate strength as high as 115,000 psi. with an elongation in 2 in. of 23% and reduction in area of 65%.

### *Armor Bolts*

A consideration of the enormous forces concerned on impact points out the necessity of properly securing armor to the structure of the ship. Experiment only increases the importance to be attached to the subject. Many experiments have conclusively shown that all flexible mountings, such as steel springs or rubber buffers, designed to absorb energy, cushion the plate, or extend the time interval in which the plate can act, are not only of no value but are, on the contrary, a source of actual weakness.

As it is impossible to fit armor plate snug against the shell, the armor stands off about 2 in. This space is filled with concrete, which provides an equally distributed support. Abutting edges have a double tongue-and-groove key which is driven in endwise; and plates which meet at angles are rabbeted, as shown in the sketch.




*Method of Keying Horizontal Joints and of Supporting Armor to Ship's Plating*

Armor bolts are spaced to provide one bolt for every 5 sq.ft. They are made from good quality, 3½% nickel steel, for the bolt must be strong enough to hold the plate and be ductile to permit the plate to warp and spring under impact without cracking.

### *Light Armor*

During the World War, insistent demand resulted in the development of a third type of armor, generally called "light armor", to protect personnel and instruments against machine-gun fire from aircraft. Light armor is also used to afford protection to machine guns, light artillery, boats, and its use may be extended to the protection of personnel and vital parts of aircraft.

In some of these uses, as for instance aircraft armor, the greatest possible protection must be secured with the least weight — a condition imposed on all armor, in fact, but most accentuated in these uses. In this type of armor the metallurgist can use his utmost skill, for the mass is small. One might almost say that laboratory methods may be followed.

Generally speaking, this armor resembles Class B armor, although many special and expensive alloy steels are being tried. In them we find silicon, manganese, vanadium, zirconium, cobalt, chromium, and nickel in various proportions and combinations. Plates have been tested giving, with fair ductility, strengths up to 250,000 psi.

One fact seems to stand out — as desirable as is strength — good ductility is a necessity.

Official O.W.I. Photo by Rittase

*M-4 Takes Some Heavy Going on the Testing Grounds*

**Known as the General Sherman to the English in Libya, where it was a prime factor in Rommel's rout. Armored hull and turret are both one-piece alloy steel castings**

# Tank Armor*

By Brig. Gen. G. M. Barnes

ARMOR provides protection and cover for the working mechanisms and personnel. It is of interest to note that, according to World War records, 60% of battle casualties resulted from low velocity fragments thrown from projectiles. It is, therefore, obvious that even thin armor provides a great degree of protection.

Armor, unfortunately, is the greatest weight producing factor in a tank and offers the greatest problems in machining and fabrication. It is the present practice of the United States Army to use rolled face-hardened armor plate. This type of plate gives the greatest protection from small caliber bullets up to caliber 0.50. However, it is not well suited to withstand the shock of larger caliber projectiles. For lightly armored vehicles it is necessary to use face-hardened plate because this is the only type of thin plate which will keep out the bullets from high powered machine guns.

Rolled homogeneous plate offers the best ballistic values against projectiles larger than machine gun bullets. It furnishes protection against small arms bullets which cannot penetrate so great a thickness, and is also a superior type of plate for absorbing the shocks of heavier caliber cannon projectiles. It can be welded and formed.

The use of cast armor in the United States is increasing. Up to the present time, cast armor has been made to give about 90% of the ballistic value of rolled homogeneous plate. Cast armor has an important design advantage in that it can be contoured and sloped to any desired shape and thus achieve some advantage in ballistic values.

Tank plates may be riveted or welded together. While we completely welded a tank as early as 1933, and while we have made armor plate castings at Watertown Arsenal over a long period of years, welding and casting have entered the field of design extensively only during the last year. The urge to weld or cast comes largely from the desire to eliminate riveted structures which are somewhat weak ballistically. The rapid development in welding armor during the past year insures that welding will be extensively used in tank manufacture in the future.

*From an article entitled "Supertanks" in *Army Ordnance*, March-April 1942 issue.

# Tank Design*

IT IS *apropos* in more ways than one to describe the tank as a "land ship". In both ships and tanks the competition of gun versus armor was largely a metallurgists' war, as each step was taken first by the defense to thicken or improve the armor, then by the offense to provide guns with projectiles having higher velocity and better penetration. In both ships and tanks the cry for great speed led to an unbalanced product. The view later prevailed that thick and heavy protection alone for a battleship was not sufficient. A highly efficient fighting weapon needed greater gun power coupled with speed and long sea-keeping qualities. The armor must be reduced in thickness by imparting to it higher qualities of resistance.

Many features common to the sea ship confront the designer of the land ship — the interrelation of speed, protection, offensive power, adaptability to varying conditions, and maintenance in action for long periods. Just as ships intended to operate near shore bases can be built with simpler fitments than those which have to operate for long periods on any ocean, so a tank intended for fighting in enclosed European countries may be different from those operating in open desert areas, where they fare far and are long absent from their bases.

It might be stated very roughly that in a fight the vulnerability of a moving target varies as its size, but inversely as the square of its speed, but the difficulties of design are increased in a degree somewhat approximating the square of the weight and the cube of the speed. It will be clear, therefore, that the result is a compromise between many diverse and exacting requirements; it must also be constructable rapidly and in large numbers from materials available.

Take the question of armor. The ½-in. tank armor of the last war needed only to turn the bullets of the machine gun of the day. Such scant protection could not be accepted in this war, and as better and better anti-tank weapons have been introduced by both sides, so has arisen an insistent demand for thicker and thicker armor, despite its improved quality. Now armor is heavy, and the designer must do his best to counteract the load by endeavoring to decrease the cubic contents of the "box" he has to protect. *(Cont. on p. 432)*

*From "Armored Fighting Vehicles in 1942", *The Engineer*, Jan. 1, 1943, p. 15.

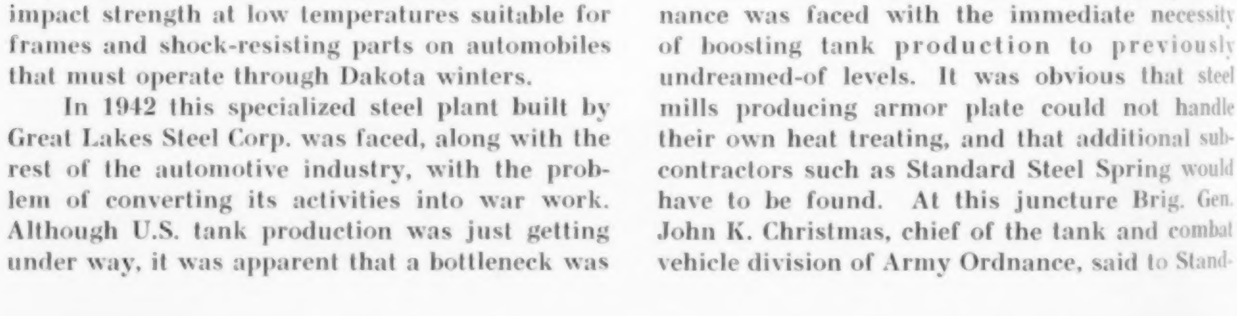
By Lloyd Stouffer
*Detroit, Mich.*

# Network of Shops for Heat Treating Small Armor

Current success of America's tank production is intimately tied to the automotive industry. It stems from the development of a steel plant in the Detroit district, the construction of a 96-in. continuous sheet mill, and a lengthy research program to discover high tensile steels with good impact strength at low temperatures suitable for frames and shock-resisting parts on automobiles that must operate through Dakota winters.

In 1942 this specialized steel plant built by Great Lakes Steel Corp. was faced, along with the rest of the automotive industry, with the problem of converting its activities into war work. Although U.S. tank production was just getting under way, it was apparent that a bottleneck was going to develop in the melting, heat treatment and cutting of armor plate. The nation's steel production, furthermore, even as early as the summer of 1941, was being slowed up by the time required to put the enormous tonnages in the making through the heat treating and straightening operations. Here another branch of the automotive industry became interested. Standard Steel Spring Co. reasoned that with its equipment and experienced personnel it ought to be able to take the job of heat treatment off the hands of some producing mill, and it was particularly interested in the new alloy, low in critical elements, developed by the Great Lakes' staff. Preliminary tests were so satisfactory that an arrangement was made between the Army Ordnance Dept., the steel producer, and the spring company, and by the end of 1941 the latter's three plants were operating at capacity on heat treatment of armor.

Then came Pearl Harbor, and Army Ordnance was faced with the immediate necessity of boosting tank production to previously undreamed-of levels. It was obvious that steel mills producing armor plate could not handle their own heat treating, and that additional subcontractors such as Standard Steel Spring would have to be found. At this juncture Brig. Gen. John K. Christmas, chief of the tank and combat vehicle division of Army Ordnance, said to Stand-



*Modern Furnaces in Spring Company's Plant Adapted to Heat Treat Medium Armor Plate*

ard Steel Spring, "Haven't you competitors that have heat treat facilities such as your own which can be organized into a pool to handle the job?" Standard Steel Spring said it would try and gathered a group of manufacturers of automobile springs and hardware, stampings, stoves, furnaces, bumpers, saws, steel doors, railroad equipment, bathtubs, shovels — even bricks.

This organizational job took 18 days!

The organization is simplicity itself. The Detroit office schedules production according to the capacity and facilities of each member plant, and it buys all the steel from the mill. Each unit of the network receives the armor in the form of rolled plates. It heat treats and straightens the plates, then cuts them according to specifications supplied by the particular tank builder it serves.

In September, production was 60 times the level of May. The pool is turning out the amazing number of 1200 different shapes and sizes of armor, from thick to thin, for tanks and virtually every other Army vehicle carrying armor.

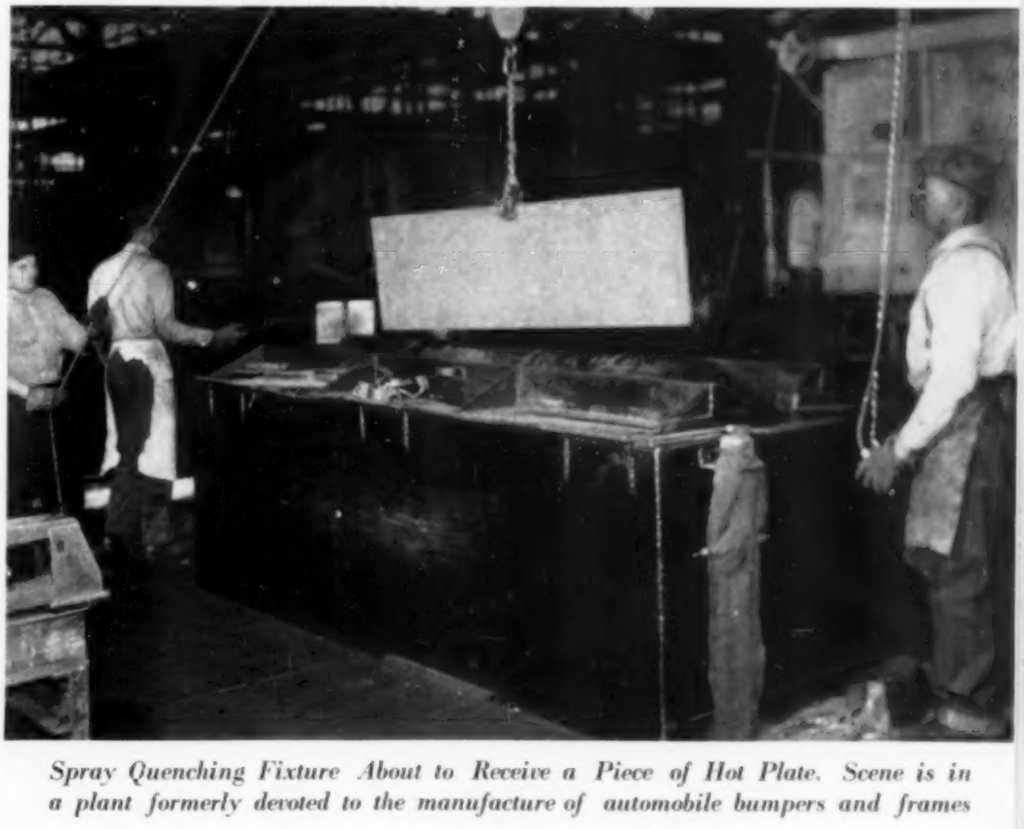
Standard Steel Spring not only is the central office for the entire network, but it serves as a clearing house of technical information. Improved production processes and short cuts are constantly being devised in individual shops, and these are made available to all. It is no secret that the quality of the steel itself is being constantly improved — reducing the use of its few critical alloy contents, boosting its ballistic rating, and cutting its cost. The cost from the start has compared very favorably with that of conventional plate manufacture.

Although the organization was set up at a time when plant expansion was no great problem, Army Ordnance decided that in this case existing plants and existing facilities, so far as humanly possible, would be used. This decision saved months of time.

In a less serious crisis, engineers would have laughed at some of the makeshifts that were devised. One of the subcontractors, for instance, is a former brickyard, making use of brick kilns as heat treating furnaces. One plant is using lathes salvaged from an abandoned limestone quarry, covered with 40 years of limestone dust. Although the old lathes are not capable of close-tolerance work, they are adequate, after overhauling, for trimming armor plate, which usually does not require a tolerance of less than 0.02 in.

Conversion was accomplished in the various plants in periods ranging from 30 to 90 days, and in all cases with the barest minimum of new machines and equipment. Armor plate ceased to be a bottleneck in the tank program by the middle of 1942. The diversity of the plants makes possible allotment of specific jobs to the shops which are best suited to handle them. A specialty shop is geographically close to virtually each one of the prime producers which uses the network's armor plate. Furthermore, scattered about the country as they are, the plants run much less risk of bombing than would be the case with one or two huge central plants; fire, flood or other disaster could visit several of the shops before the flow of plate would be seriously impeded. The Army Ordnance men who have fathered the development think it exemplifies what their chief, Maj. Gen. L. H. Campbell, Jr., head of Army Ordnance, means when he says:

"If you want to eat an elephant, first cut it up into small pieces."



*Spray Quenching Fixture About to Receive a Piece of Hot Plate. Scene is in a plant formerly devoted to the manufacture of automobile bumpers and frames*

By Edgar Brooker
and Loren L. Elliott
*Ordnance Engineers, U. S. Army*

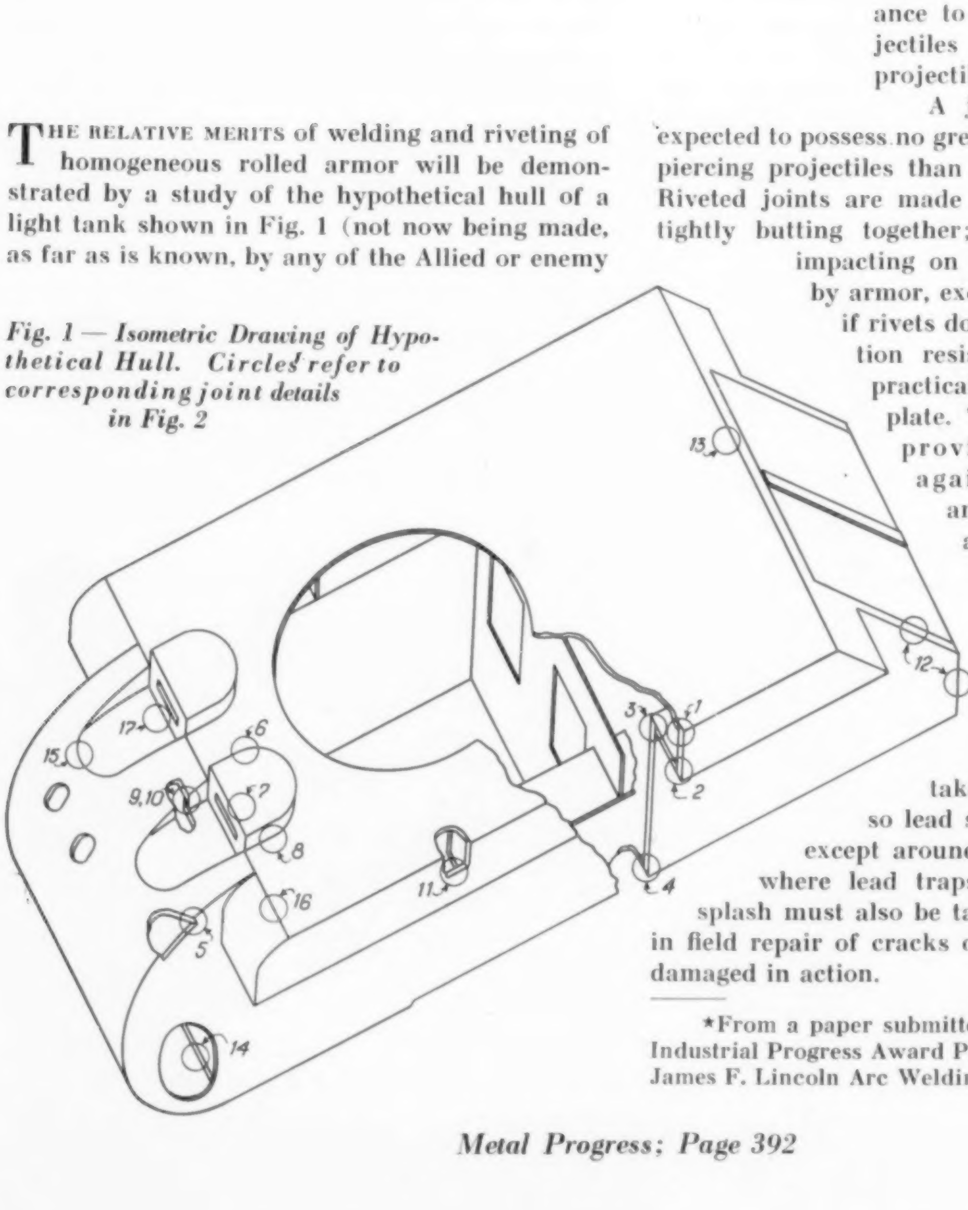
# Welded Hull for Combat Tank*

THE RELATIVE MERITS of welding and riveting of homogeneous rolled armor will be demonstrated by a study of the hypothetical hull of a light tank shown in Fig. 1 (not now being made, as far as is known, by any of the Allied or enemy governments). It will be shown that welding provides superior ballistic properties, and saves weight, labor and machine tool time.

Riveted joints for armored structures are not quite as bad as the newspapers have indicated, because riveted tanks have given a very good account of themselves. "Efficiency" of riveted joints, in the structural engineer's meaning, has small importance, for the integrity of a protective hull lies in resistance to armor piercing projectiles and to shock from projectiles that do not penetrate.

A joint in armor can be expected to possess no greater resistance to armor piercing projectiles than the armor plate itself. Riveted joints are made with the armor plates tightly butting together; hence all projectiles impacting on the joints are opposed by armor, except for the cracks, and if rivets do not shear, the penetration resistance of the joint is practically as good as the virgin plate. The butt strap or straps provide extra thickness against penetration. Ball ammunition impacting against a tight crevice between armor plates becomes liquid and will splash several inches before being stopped unless a lead trap is installed. The lining of riveted tanks takes care of this hazard, so lead splash is of no concern except around openings in the hull, where lead traps are installed. Lead splash must also be taken into consideration in field repair of cracks occurring in bent hulls damaged in action.

*Fig. 1 — Isometric Drawing of Hypothetical Hull. Circles refer to corresponding joint details in Fig. 2*




*From a paper submitted to the recent $200,000 Industrial Progress Award Program conducted by the James F. Lincoln Arc Welding Foundation.

### *Shock Resistance*

Low shock resistance is the chief weakness of riveted joints. This is measured by the use of soft deforming projectiles which have inferior penetrating power. The method consists of determining the critical destructional velocity of these soft-nosed slugs for virgin (unwelded) plate, following which lower velocities are selected for shocking jointed plates.

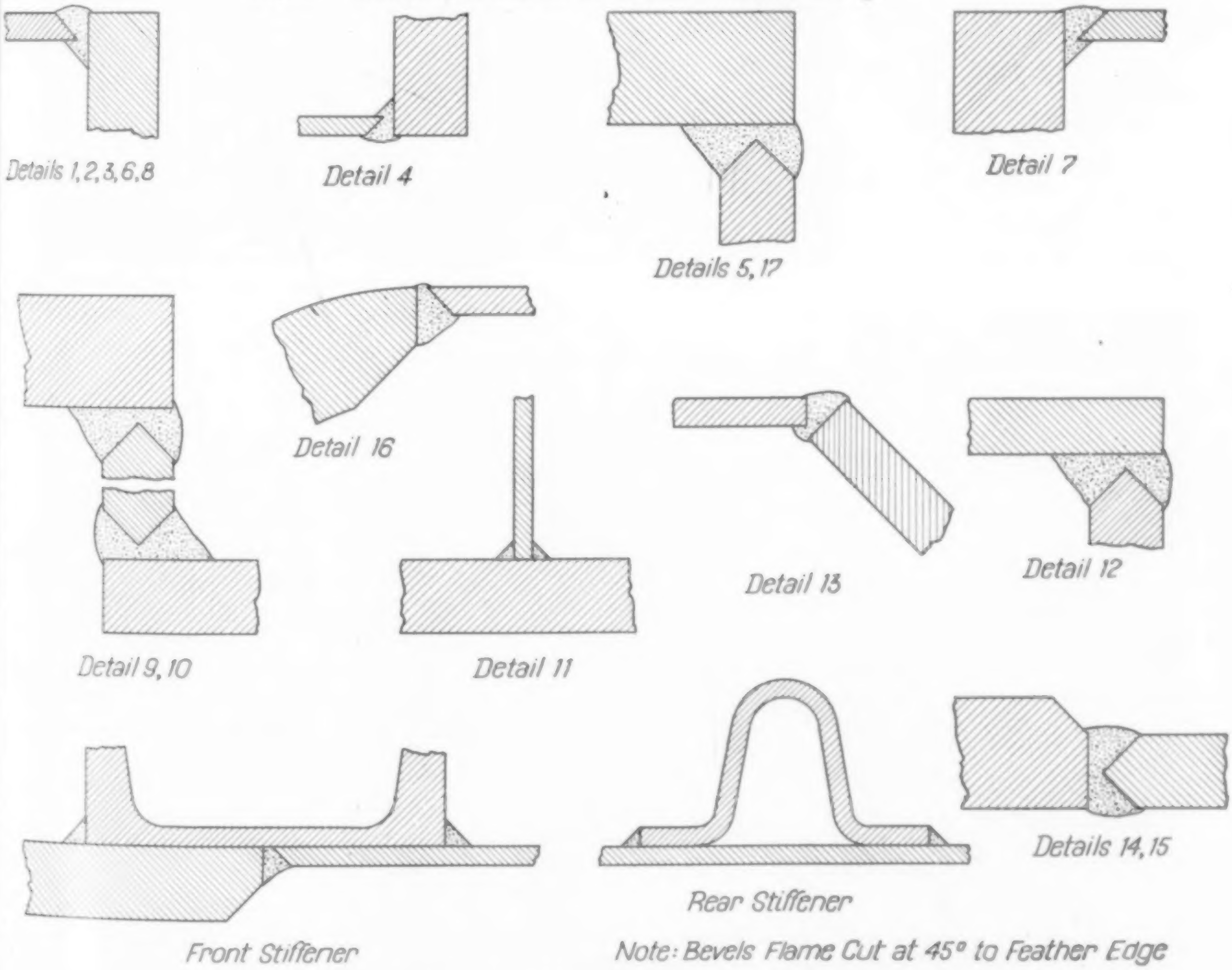
Three tests of this sort are photographed in Fig. 3, 4 and 5, where the only variables are the method of making the joints and the impact from the projectile. Details are shown in the captions, and the reasons for selecting the "H" assembly of joints will be given later.

Five rivet heads were thrown from the back side of Fig. 3, the hot riveted assembly, by a rather moderate impact. A heavier impact wrecked the cold riveted assembly (Fig. 4), but three similar heavy blows did not crack any of the welded joints.

In the welded assembly the crossbar of the H was welded last so as to produce a locked-up stress condition. Three slugs were fired at this plate with striking velocities of 1115, 1112, and 1216 ft. per sec. in order of firing. Round No. 1 struck at 1115 ft. per sec. and 3 in. center-to-center distance from the vertical leg weld, hence did not stress the weld sufficiently to prove anything. This one impact against a riveted plate would have broken it in at least two parts. Rounds No. 2 and 3 struck in a highly stressed area and *no* cracking occurred on the front or back sides of the joints. This shock will frequently break an unwelded plate.

Welds in armor should possess resistance to projectile penetration equal to that of the plate, but stainless steel weld metal is actually lower in penetration resistance than armor plate. This deficiency does not exist in welded joints when butt straps are used or when weld reinforcements are not removed. The arrangement of welded joints in the hull of Fig. 1 is such that rare or lucky hits only would hit them. The armor and

*Fig. 2 — Details of Welds in Tank Hull Sketched in Fig. 1*



welds of this vehicle are sufficiently thick that any projectile smaller than the 37-mm. size cannot penetrate at battle range. 37-mm. or heavier anti-tank projectiles are larger in diameter than the width and root gap of any of the welds used; hence if such impacts should occur on these joints the projectiles would be opposed by plate as well as by weld metal. Therefore, penetration test data frequently show that the penetration limits of the welded joints with normal reinforcements are 100% of that specified for the plate. The low penetration resistance of stainless weld metal therefore does not cause points of weakness in a hull.

It was prophesied that welded joints would fail at regions considerably removed from the point of projectile impact, because of the great internal stresses presumed to exist in a welded hull. For this reason the H plate was criticized; impact No. 1 on Fig. 5, for example, stressed the weld metal in tension in the crossbar of the H on the face side. With few exceptions the welded joints in a tank hull are so located that projectile impacts primarily place the weld metal in compression.

When it became possible to conduct ballistic shock and penetration tests of a welded hull, the use of H plates for testing and developing weld quality was justified. Fifteen 75-mm. slugs impacted against one side of a welded hull caused only local failures adjacent to the points of impact. No cracks occurred

*Fig. 3 (above) — Hot Riveted H-Plates, Struck With One 75-Mm. Slug at 906 Ft. per Sec. (96 Ft-Tons). ¾-in. high tensile rivets; 3½-in. pitch; ⅝ x 5-in. butt straps. Five rivets sheared on 12-in. crossbar of H.*

*Fig. 4 (below) — Cold Riveted H-Plate, Struck With One 75-Mm. Slug at 1246 Ft. per Sec. (181 Ft-Tons). ¾-in. high tensile rivets; 3½-in. pitch; ⅝ x 5-in. butt straps. Nineteen rivets sheared and 54 in. of joint broken*

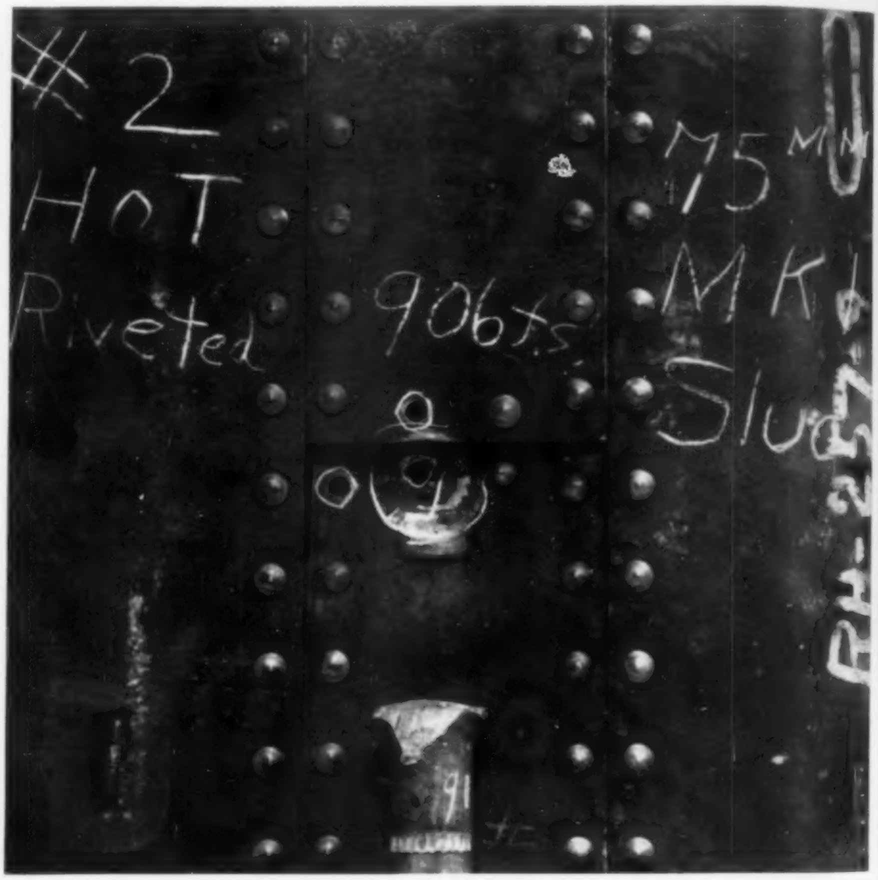




*Fig. 5—Welded H-Plate Struck With Three 75-Mm. Slugs at 1115 to 1216 Ft. per Sec. (Total of 463 Ft-Tons). No cracking*

elsewhere that could be explained by shock wave propagation or by excessive internal stresses. Just as shock impacts located more than 2 in. center-to-center distance from the welds in H plates caused no damage, so in the welded structure, ballistic damage occurred only within a small area surrounding the depression caused by the projectile. Internal stress was not evident.

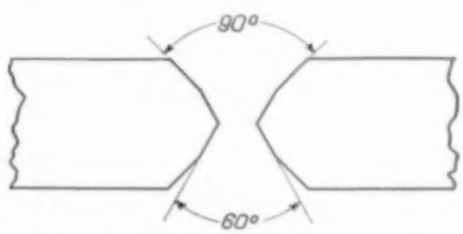
By that same token the two tests on riveted joints in Fig. 3 and 4 are abnormal, for in actual hull construction the most common joints are angle butts in which the plate edges are in close contact and support or back up each other.

Figure 2 (page 393) illustrates the welded joints in the hull proposed in Fig. 1. It will be noted that simple fillet welds are avoided for joining of outside plates except those on the bottom. Fillet welds at the inside transverse, front stiffener joining the curved plate to the floor plate are far enough aft that ballistic impact is of no concern.

Root gap openings in all joints should permit complete penetration of weld metal in the two central passes. The most difficult part of making a sound weld with stainless steel electrodes in armor is the deposition of sound root passes with complete penetration. The plate edge preparation for this vehicle requires 45° bevels made in such a way that the flame cutting machine will not have to ride or be guided upon the cross-section of any plate.

Welds in all self-hardening steels, such as armor, cause a hard zone alongside the weld, commonly called the heat affected zone. The Knoop tester shows the maximum hardness to be approximately 450 in the plate immediately adjacent to the weld metal. Thus it is reasoned that a layer of low ductility adjoins the stainless steel weld in armor, unless the joint is post heated. However experience shows that this operation is not necessary or practicable for rapid production. The 45° bevels of details No. 9 and 10, for example, are justified because this brittle zone is increased in surface area over that which would result if a smaller included angle were used.

Simple butt welded joints with no beveling have been made and have given fair results in ballistic shock. Such joints use a minimum amount of weld metal, which is an advantage for reducing the consumption of critical alloys and minimizing welding hours, but butt welds are not favored for high shock strength. Very successful butt joints in the thicker plates are made with "broken back" chamfering, thus:




## *Advantages in Production*

Welded construction also offers numerous advantages over riveted construction from a tank production standpoint:

Plate preparation for riveting requires almost perfectly flat plates to *(Continued on page 430)*

By M. F. Garwood and E. H. Stilwill
*Chrysler Corp., Detroit*

# Substitute for 90 Cu, 10 Sn Bearings*

WHEN STARTING the manufacture of the rapid-fire, 40-mm. anti-aircraft Bofors gun, it was necessary to adapt the Swedish drawings to American units, and the foreign metal analyses to standard alloys available to us, and later to make other changes in metals on account of critical shortages.

Various non-ferrous alloys were studied in quest of one, preferably tin-free, which would successfully replace the QQ-B-691 composition 5 material specified for various bushings and bearings in this gun. This alloy, considered to be a very good material in these applications, contained 7.5 to 11.0% tin. Published information indicated that a copper-silicon alloy might satisfy the requirements and a comparative investigation of chemistry, physical properties, and frictional characteristics was conducted. The table shows some of the results.

The two compositions B and C fall within a general Federal specification for cast copper-silicon alloys, QQ-C-593, and the physical properties specified seemed to be adequate for our needs and these properties were met by the commercial alloys.

By our tests the cast silicon bronzes investigated had equal or better frictional characteristics than the 90-10 bronze. The wearing characteristics in friction tests were also favorable, and in addition, the new alloys were less susceptible to seizure. The data were taken under conditions of boundary lubrication and do not represent all the results accumulated; however, since these parts will have scanty lubrication the indicated values are most nearly applicable.

Wear tests were made by measuring the area of the plastically deformed or abraded material which resulted from one set of test conditions, and are therefore comparative only. Seizure tests were made to find the maximum load in psi. that the material would carry under a given set of frictional conditions without seizure.

The results of the above investigation indicated that a cast copper-silicon could be successfully substituted for the tin bearing metal and our recommendations were made accordingly.

**Tests on Bronze and Silicon-Copper Bearings**

| | 90-10 Bronze QQ-B-691A Class 5 | Si-Cu QQ-C-593 | Alloy B | Alloy C |
|---|---|---|---|---|
| Chemical limits or analysis | | | | |
| Silicon | .... | 1.0 to 5.0 | 3.24 | 4.03 |
| Iron | 0.10 max. | 2.5 max. | 0.44 | 0.10 |
| Tin | 7.5 to 11.0 | 2.0 max. | 0.68 | .... |
| Zinc | 1.5 to 4.5 | 5.0 max. | 5.1 | 0.30 |
| Lead | 0.3 max. | .... | >0.05 | .... |
| Nickel | 1.0 max. | .... | >0.05 | .... |
| Manganese | .... | 1.5 max. | 0.02 | 1.05 |
| Aluminum | .... | .... | nil | .... |
| Phosphorus | 0.05 max. | .... | .... | .... |
| Tensile properties | | | | |
| Ultimate strength, psi. | 40,000 min. | >45,000 | 49,400 | 43,800 |
| Yield point, psi. | .... | .... | 19,060 | 14,370 |
| Elongation, % | 20 min. | 15 min. | 26 | 31 |
| Reduction of area | .... | .... | 38.5 | 42.3 |
| Frictional characteristics *(a)* | | | | |
| Coefficient of friction *(b)* | 0.229 to 0.256 | .... | 0.121 to 0.139 | <0.139 |
| Wear factor *(c)* | 13.0 to 13.9 | .... | 12.0 to 14.8 | <8.2 |
| Seizure factor, psi. *(d)* | 350 | .... | 425 | 1600 |

NOTES: *(a)* Not a part of the specification. *(b)* Based on boundary lubrication conditions. *(c)* Amount of material worn away during test. *(d)* Load at incipient seizure.

*Extracts from "Material Applications in Gun Manufacture" read before Society of Automotive Engineers' 1943 Convention.

# Sources of Hydrogen in Steel and Means for Its Elimination

By Carl A. Zapffe
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*Columbus, Ohio*

"BEHAVIOR and Control of Hydrogen in Steel" was the ambitious title of a talk given to the Notre Dame Chapter, ⊕, about a year ago. Two portions of it have already been published in *Metal Progress*. The first, entitled " 'Fish-Eyes' in Steel Welds, Caused by Hydrogen", appeared in the August 1942 issue, and presented evidence that these defects as well as flakes in forgings are caused by hydrogen gas, liberated from solution in the surrounding metal while it cools, and accumulating in porosities in the metal. The second installment (December 1942) was entitled "Defects in Cast and Wrought Steel Caused by Hydrogen", and for the most part described laboratory experiments on sound metal which caused the appearance of defects well known in practice, such as shatter cracks, flakes, white spots, and pinholes. The present and final portion will deal largely with enameling defects due to hydrogen in steel, and will conclude with some suggestions about what can be done to avoid these numerous types of troubles.

### *Principal Sources of Hydrogen in Steel*

The injection of hydrogen into solidifying metal from the decomposition of moisture and organic materials in the sand mold (as briefly discussed at the end of the article in December's *Metal Progress*) introduces the principal topic in considering important sources of hydrogen in steel. True, there are many other sources; for example, a 1% nickel steel made from unannealed electrolytic nickel could inherit enough hydrogen from that small addition to embrittle it from end to end; and the furnace atmosphere can be adjusted sometimes to confer either ductility or embrittlement because of the hydrogen in the combustion gases. Again, hydrogen may be absorbed in serious quantities from the carburizing pack, and from certain reducing gases (protective atmospheres) in annealing furnaces.

Nevertheless, the principal source of hydrogen for most steels is water, whether liquid, vapor, or chemically combined as in iron rust. Water possesses the greatest concentration of hydrogen available to steel — a thousandfold greater than one atmosphere of the pure gas itself — and the great avidity of iron for oxygen stands as an ever-ready release for that hydrogen. The formation of *only one ounce* of iron rust from water, please reflect, liberates about 1000 cu.in. of hydrogen, measured under standard conditions, which is sufficient hydrogen to embrittle 500 lb. of the best steel from one surface to the other.

Some of the best supporting evidence for this assertion comes from welded joints. In Fig. 19 are shown the tensile fractures of two sets of weld specimens, made under commercially identical conditions except that the upper row was made in humid weather, the lower in dry weather. If you compare the proportions of brittle metal in each, further comment is useless.

To name a few other instances: The strong effect of humidity in steelmaking has long been noted — as an anomaly — by melters who find steel bleeding in the mold on damp days, by foundrymen who subsequently note impairment of ductility and prevalence of white spots, and by vitreous enamelers who find steels made in the summer, when the humidity is generally high, develop more defects in the enamel than do winter-made steels. The stultifying factor has been the complete absence of information from ordinary chemical analyses, which show no sys-

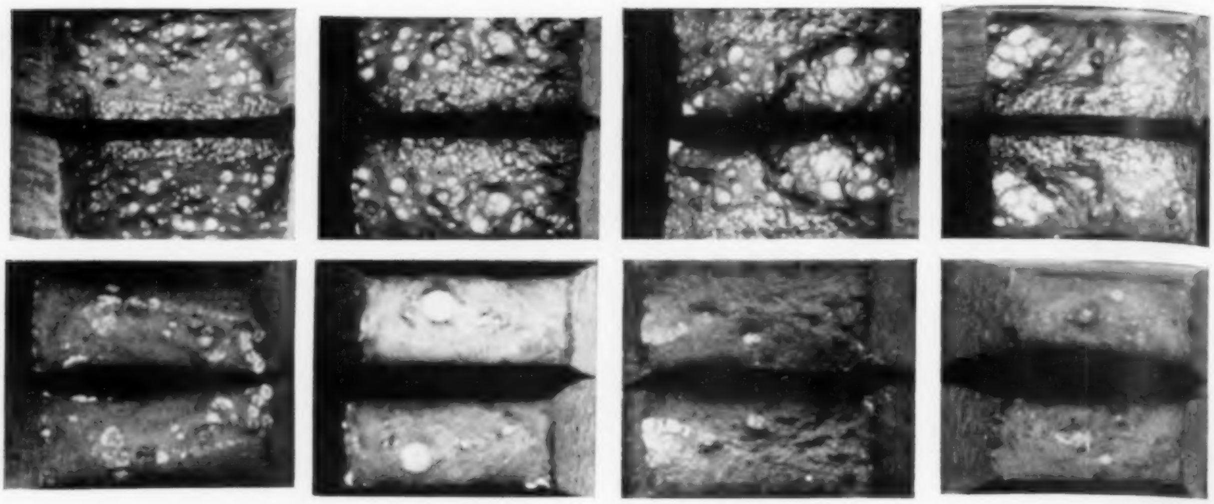


*Fig. 19 — Tensile Fractures of Weld Metal; Upper Row Made in Humid Weather; Lower Row Made in Dry Weather. (Figures are numbered consecutively with those in previous articles)*

tematic differences; however, when the analyst knows what to look for, carefully conducted analyses for hydrogen, though difficult to make, readily show a marked difference.

Figure 20 illustrates a similar effect of the small amount of moisture ordinarily contained in the coating of welding electrodes. With the electrode previously baked at 108° C., only a homogeneous and restricted "silver streak" appeared at the interbead disjunction (left-hand pair). Because this electrode was cellulose-coated, such hydrogen embrittlement is normal and is easily alleviated by subsequent treatment. The untreated electrode, however, led to the heterogeneous deposition of hydrogen shown in the central pair — a scattered mass of fish-eyes marking each of the tiny voids probably caused by the hydrogen-oxygen reaction. At the temperatures of the weld puddle, of course, water readily dissociates and can dissolve in the steel as elemental hydrogen and oxygen, which gases later may recombine to form trapped steam when cooling reduces their solubilities. Two specimens welded in an atmosphere of steam are also shown at the right of Fig. 20, and it is significant that the defacement is but little greater than that caused by the moisture ordinarily contained in such undried cellulose coatings.

The effect of moisture on weld metal is generalized in Fig. 21. Interestingly, not only is the ductility badly impaired, but the tensile strength is also decreased to a noticeable extent. Hydrogen alone affects the tensile strength of steel little, if at all; in these welded pieces, consequently, either internal stresses initiate cracking or the hydrogen-oxygen recombination, on cooling, weakens the steel by forming interdendritic voids or blowholes.

## *Enameling Defects*

From vitreous enameling one can obtain especially vital information regarding the effects of moisture, for the enamel coating registers, in a sensitive manner, any gas that effuses from the steel base. For illustration, many users of steel and iron have traced what they call "hereditary phenomena" to excessive charges of scrap.

At Battelle Memorial Institute we made a heat of cast iron, split it four ways and poured it in carefully dried molds. The first cast was normal enameling iron. Then some extra scrap was added, melted, the bath brought to heat and a second casting was poured. Hydrogen was then bubbled through the melt, and a third casting was poured. Through the remaining metal nitrogen was bubbled to remove the hydrogen, and the metal was cast.

When fired with vitreous enamel, the nitrogen-treated casting showed no blistering whatsoever; the normal casting showed occasional blistering that responded to "boiling down"; the specimen to which extra scrap had been added developed marked blistering; and the hydrogen-treated one was ruinously defaced. Qualitatively, the degree of blistering ranged from zero to a maximum in accordance with the hydrogen content of the iron.

The importance of moisture in the mold was demonstrated similarly. A heat of cast iron, dehydrogenized by a nitrogen treatment, was cast partly in a carefully dried mold and partly in a green sand mold. The astonishing results are shown in Fig. 22 (page 400); the dehydrogenized specimen cast in green sand blistered as badly as though it had been deliberately saturated with hydrogen during melting.

Then there is moisture from another source — the enamel itself. Firing requires fairly elevated temperatures, bright red heats, and the clays contained in the enamel carry water of hydration that cannot be baked out at moderate temperatures. The actual content seldom exceeds 1% and has therefore been largely disregarded. Recently, however, enamelers have traced differences in their product to the differences in water content of various clays used as the base for the enamel mixture, and the results are in exact accordance with the present argument. During firing, that water reacts with the iron to form a fluxing and adhering iron oxide, whereupon hydrogen — in volumes many thousands of times greater than the volume of oxide produced — is freed for possible absorption by the iron. Absorption of that gas, in addition to the more or less important threshold quantities already in the iron or steel, forms the basis for most of the blister-type defects occurring during firing, and the chip-type defects occurring after cooling.

Figure 23 illustrates this absorption. On that part of the sheet coated only on one side, hydrogen was injected from the enamel only from one side, and could escape out the other; whereas on the adjoining section the gas was injected from both sides by the enveloping enamel. Later, when the enamel was cool, the gas slowly effused and exploded away chips or "fish-scales" of the solid covering.

A different registration of the same phenomenon appears in Fig. 24. This steel sheet was given an adherent oxide coating by annealing in air. The oxide was then removed by sand blasting except over an area depicting the initial N. Vitreous enamel fired over this specimen developed "fish-scales" only over portions not protected with oxide. (The few defects visible over the oxide presumably resulted from unavoidable breaks in the oxide layer.)

The explanation we offer is that the oxide prevented any reaction between hot iron and moisture. The segregation of fish-scales along the edge of the initial is more difficult to explain. A zone of weakness is quite conceivable, for each chip, it may be noted, overlays the bare metal and not the oxide. Over the rest of the bare area is a mass of small fish-scales which do not reproduce well in the engraving.

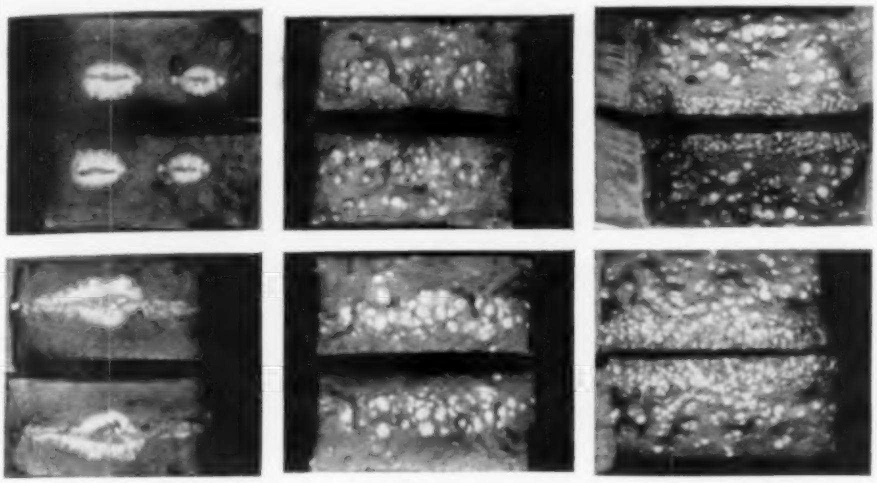
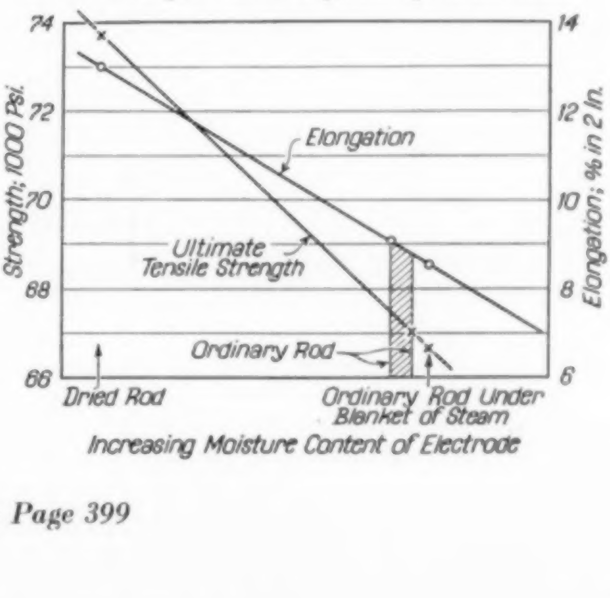


*Fig. 20 — Tensile Fractures of Weld Metal Made in the Presence of Water Vapor. Central pair made with ordinary electrode, cellulose coated. Left pair made with same, baked at 108° C. Right pair made in atmosphere of steam*

With blistering, an almost uncanny function of hydrogen absorption transpired. We refer to it as the "resurrection" specimen. A steel sheet was prepared similar to the one just discussed, except that scale remained in the form of a cross lying lengthwise and crosswise on one surface. Enamel was fired over the entire piece, with results similar to the N, described above. Both enamel and oxide were then removed by a thorough sand blasting, so that an entirely clean sheet remained. On this a coat of enamel was again fired, and the cross was resurrected (Fig. 25).

This phenomenon simply depends upon differential hydrogen absorption and content. From

*Fig. 21 — Approximate Effect of Moisture Present on the Strength and Elongation of Weld Metal*



the first firing the piece absorbed hydrogen only over the bare areas surrounding the cross. From the second firing, absorption was uniform, so that the total hydrogen content varied across the piece in accordance with the configuration of the cross.

For many years enamelers have debated the cause of such recurrence of blistering, which they call "reboiling". Surely this experiment offers a ready explanation.

### *Avoiding Defects Caused by Hydrogen*

About this last and most important part of our discussion I have the least to say. The investigation at Battelle Memorial Institute is proceeding from the standpoint that the best understanding of the problem should lead to its surest cure. Consequently, we hesitate to make any positive recommendations at a time when we are first beginning to recognize the true nature of the hydrogen-iron relationship. Many precautions, such as controlling the scrap additions, drying the charge, regulating the flame, and slow-cooling the ingots and forgings, are so well understood and so widely practiced that they already stand in the literature as metallurgical *clichés*. We are hopefully seeking a specific, and until it is found we can only temporize.

There are advices, however, that bear close consideration. For instance, we are convinced that all the common defects in or on steel caused by hydrogen are effected only by portions of that gas trapped under surprising pressures. From that we immediately conclude that for a given type of defect there must be some threshold pressure necessary — a "critical pressure". Similarly, for each locus or discontinuity seating that defect there must be a "critical volume" of hydrogen necessary.

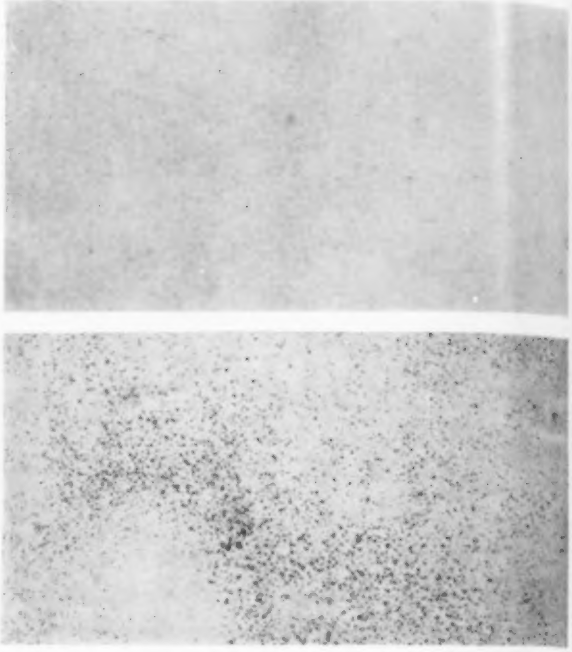


*Fig. 22 — Effect of Hydrogen in Cast Iron on Vitreous Enamel Fired on Its Surface. Top is a sample of hydrogen-free iron cast in dry mold; below is same iron cast in green sand*

We have seen that blisters in paint, chips in vitreous enamel, ruptures in electroplated coatings, blisters in steel sheet, and, finally, embrittlement of the steel itself by internal plastic disruption, require progressively greater pressures and, depending upon such factors as permeability of coatings or spaciousness of occluding voids, progressively greater quantities of the occluded gas. Thus, a steel with good ductility may develop enamel defects; and enamelable steel may still be unfit for painting.

This conception of critical pressures and volumes does lead to important conclusions, for it means that one need remove only a "critical" quantity of the gas to avoid any one type of defect. Until steelmakers revolutionize their processes sufficiently to prevent important quantities of hydrogen from entering the steel, methods for removing those nec-

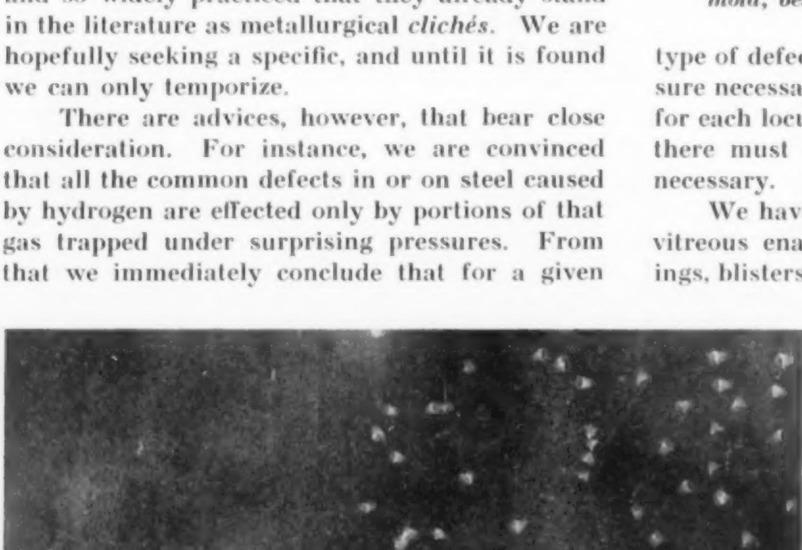


*Fig. 23—Effect of Water of Crystallization in Enamel Minerals, Which React With Iron, During Firing, to Form Iron Oxide and Hydrogen. Left portion of sheet was coated on upper side only and dissolved hydrogen escaped out of uncoated surface; right portion was coated on both sides, and escaping hydrogen blasted off scales of enamel*

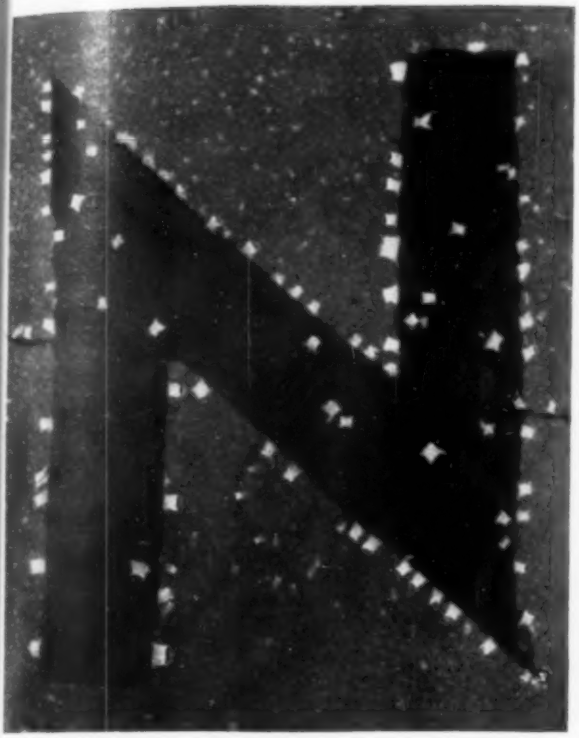


*Fig. 24 — Vitreous Enamel Fired on Steel With Sand Blasted Surface, Except for Letter N Which Retained Scale From an Oxidizing Anneal*

essary quantities have prime importance. Of course, the unfortunate situation still exists wherein the steelmaker inadvertently permits such quantities of hydrogen to be absorbed that his product is seriously damaged for consumption in certain hydrogen-sensitive processes. Alloy steels may be particularly sensitive because the carbon boil, so useful in removing absorbed gases, may not be obtainable; furthermore, some of the alloys are charged as electrolytic metals which may contain inordinate quantities of hydrogen. Again, those alloy steels having changed solubility relationships and transformations nearer the elastic range are particularly difficult to manage.

On the other hand, the steelmaker is far from being alone in his responsibility for hydrogen-caused defects — witness the enameling experiments just discussed wherein the hydrogen inherited from the steelmaking could only have a minor role, and recall the effects of pickling, cathodic electrolysis, carburizing with hydrogen-steeped compounds, annealing in reducing atmospheres containing hydrogen. Perhaps even quenching in water is dangerous for certain sensitive steels.

In electroplating, substitution of anodic cleaning for pickling or cathodic cleaning is helpful. In enameling, baking the slip to remove some of the water and controlling the furnace atmosphere with respect to hydrogen-containing gases is beneficial. For embrittlement of the steel itself, thermal treatment is the most serviceable, although cold deformation also aids in removing hydrogen.

The thermal treatments to be recommended must be modified with respect to the steel. In general, the best temperature is slightly below the solubility change at the gamma-to-alpha transformation. For plain carbon steels having no important porosity, a maximum temperature of 1300° F. is recommended. Embrittlement may persist despite extended annealing a little above that temperature. If the steel is porous — as may especially be true with weld metal — a lower temperature must be maintained, because the visible loci contain large quantities of hydrogen under enough pressure to cause re-solution, easily equivalent to annealing in pure hydrogen at much higher temperatures. We found 1110° F. to be a maximum annealing temperature advisable for weld metal; temperatures much lower, held for longer periods of time, served as well.

Until we find that long-sought panacea, little more can be said. Is it not satirical that our tiniest element becomes the Evil Genius for our most powerful structural material?

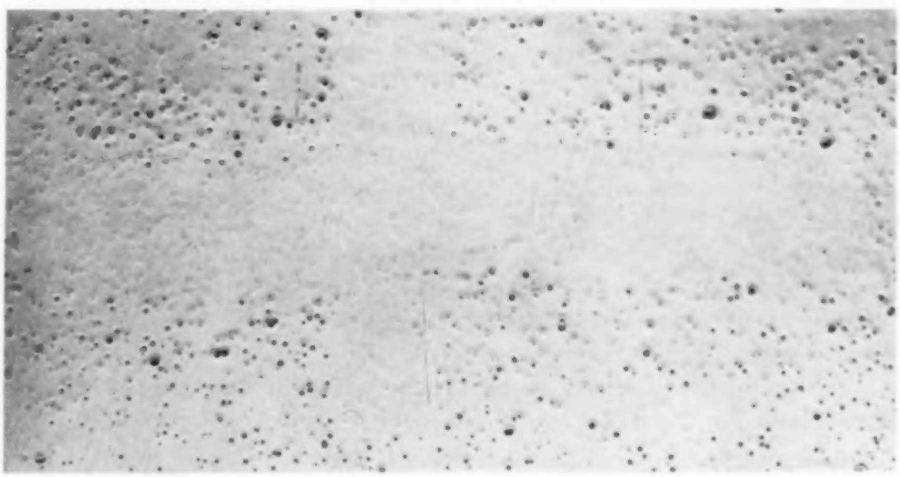


*Fig. 25 — Specimen With Oxidized Cross Was Treated as in Fig. 24, Then Completely Sand Blasted and Re-Enameled. "Resurrection" of cross, a phenomenon known as "reboiling", is due to differences between double dose of hydrogen in background and single dose on cross*

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# Calculation of Jominy End-Quench Curve From Analysis

HARDENABILITY is one of the most important characteristics of steels to keep in mind when considering their relative merits in any problem of substitution. Nearly all the other properties are dependent upon hardenability since, in general, the best properties in an alloy steel can be obtained only if the steel is effectively hardened throughout its entire section. The ability to predict the hardenability of an alloy steel on the basis of only composition and grain size (both controllable factors) has therefore become increasingly desirable. The work herein described constitutes an effort to make this possible. A method of determining the comparative hardenability of two heats of steel has long been in use by the Bethlehem Steel Co., but Grossmann's recent calculations based on composition and grain size have eliminated the comparative or relative aspects of our predictions and reduced hardenability to a quantitative basis.

Grossmann's methods, summarized in the Data Sheet in *Metal Progress* for July 1942, enable one to predict the "ideal critical diameter" ($D_I$), defined as the diameter of a bar which just hardens all the way through in an ideal quench. A bar of such diameter, with no unhardened core, has been found to consist of approximately 50% martensite and 50% primary troostite (fine pearlite) at the center. Grossmann has also found that the 50% martensite point coincides with the inflection point on the hardness curve plotted from a Jominy end-quench test.

It is the consensus that the Jominy test provides an excellent measure of hardenability for most grades of alloy steel. While the test is readily made on an existing steel, it is frequently desirable to forecast what the end-quench test will reveal on a proposed analysis or on a commercial steel not available for test at the moment. The work to be described in this paper is an attempt to develop such a method of forecasting.

The proposed method is predicated on these assumptions:

1. The hardness at the extreme quenched end of the Jominy test piece ("initial hardness" or I.H.) is a function of the carbon content of the steel.

2. The hardness at any other distance from the end of the Jominy test piece (D.H.) is a function of carbon content, alloy content, and grain size of the steel being tested.

3. The ratio of the initial hardness (I.H.) to the hardness at any other distance (D.H.) is a constant function of the ideal critical diameter ($D_I$) as determined by Grossmann, the critical diameter in turn being a function of carbon content, alloy content, and grain size of the steel being tested.

The first step in such a computation therefore consists in estimating the initial hardness (I.H.) of the quenched end — a fully martensitic structure. Of the numerous charts which have appeared in recent years showing the relationship between surface hardness and carbon content, the curve shown in Fig. 1, developed by Charles M. Parker, representing the

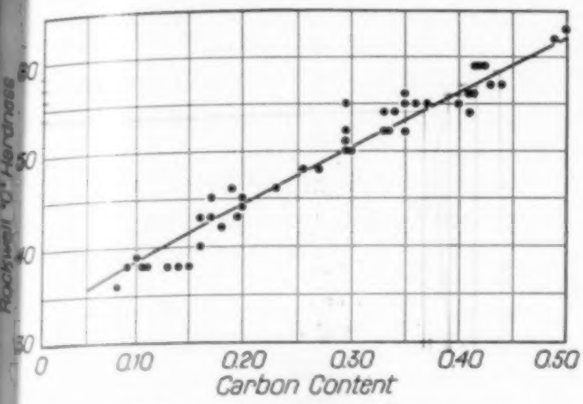



*Fig. 1 — Relation Between Sub-Surface Hardness ($\frac{1}{16}$ In. on Jominy Test Piece) and Carbon Content of National Emergency Steels (Charles M. Parker)*

hardness $\frac{1}{16}$ in. from the quenched end of the Jominy test, has been found most useful in determining the initial hardness used in the proposed method. (It is of course recognized that this curve beyond 0.50% carbon is no longer linear, and that the maximum hardness which may be attained in common alloy steels with a carbon content greater than 0.50% is approximately Rockwell C-65, irrespective of alloy or carbon content.)

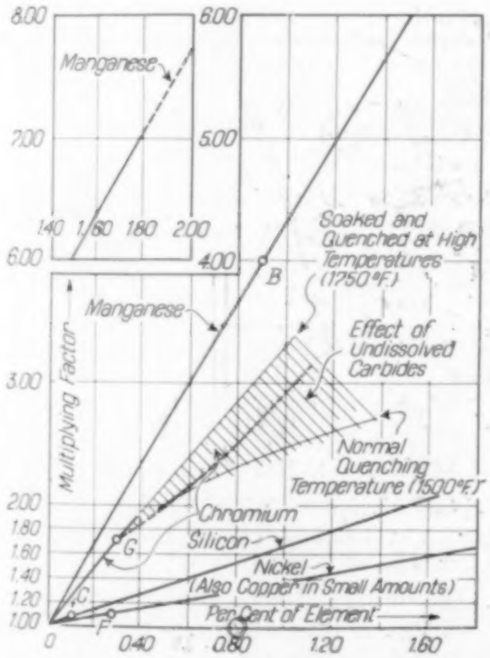
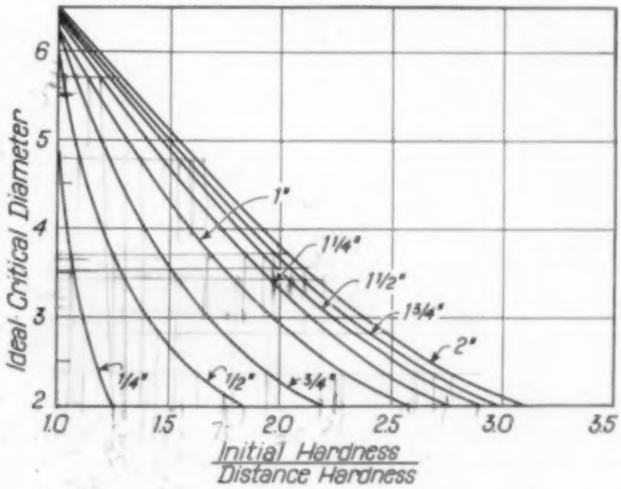



*Fig. 3 — Curves Showing Factors for the Common Alloying Elements in Steel, According to Grossmann, With Dotted Line Added to the Chromium Area by the Present Author to Represent Conditions for Normal Quenching Temperatures. (Line for silicon has also been revised to correspond with recent experiments by Crafts and Lamont, Technical Paper No. 1542, American Institute of Mining & Metallurgical Engineers)*

As a second step in the development of the proposed method, the I.H./D.H. ratios for 14 different steels were calculated from their actual Jominy curves as determined by test at $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, and 2 in. respectively. The values thus obtained were then plotted against their respective ideal critical diameters as calculated by Grossmann's system. The resultant curves plotted from averages are shown in Fig. 2.

*Fig. 2 — Ratio Between Initial End Hardness (I. H.) and Hardness at Increasing Distances Along Jominy End-Quench Test Piece (D. H.). Values indicated are averages for 14 alloy steels*




## *Influence of Chromium Contents on Hardenability*

A word of explanation is in order, as to the calculation of the $D_1$ values for the above work. The methods shown in *Metal Progress'* Data Sheet for July 1942 were used, except for chromium. As pointed out by Grossmann, if chromium is above 0.30% in the presence of molybdenum, so much undissolved carbide may be present when quenched from common commercial quenching temperatures that an unduly high $D_1$ value is obtained in the calculation. However, the writer has tentatively concluded that, in such cases, satisfactory results can be obtained by using a portion of the full chromium factor, as shown by the dotted line superimposed on Grossmann's data (Fig. 3). This line was originally plotted on the basis of data available on four heats of steel whose analyses were:

| Grade | C | Mn | Si | Ni | Cr | Mo | Grain |
|---|---|---|---|---|---|---|---|
| NE9445 | 0.44 | 1.16 | 0.48 | 0.36 | 0.40 | 0.15 | No. 8 |
| A4340 | 0.45 | 0.68 | 0.24 | 1.65 | 0.70 | 0.25 | 7 |
| A4150 | 0.51 | 0.85 | 0.28 | 0.20 | 0.98 | 0.20 | 8 |
| A4137 | 0.38 | 0.67 | 0.27 | 0.08 | 1.01 | 0.18 | 7 |

Subsequent results obtained on a considerable number of heats, with chromium ranging from 0.35 to 0.93% (all steels containing molybdenum) fully justified the use of the curve as originally drawn. It will be noted that a change in the slope of this curve occurs at approximately 0.60% chromium. As yet no experimental work has been done to find an explanation for this. Some preliminary investigation has indicated that use of a linear function for chromium over the range 0 to 1.25% chromium will give satisfactory Jominy predictions, if commonly considered optimum quenching temperatures are used. It is planned to investigate the chromium factor over this entire range in an attempt to confirm this.

## *Method of Calculating Jominy Curve*

Having established the relationship between the $D_1$ values and the I.H./D.H. values at various distances, it now becomes possible to predict the hardnesses at various distances along the Jominy test piece. This is done in the following manner:

1. Calculate $D_1$ by *(a)* obtaining the base factor based on carbon content and grain size from Grossmann's curve (upper left diagram in Data Sheet for July 1942) and *(b)* multiply this by the various factors for the alloying elements contained (all as shown by the curves on the Data Sheet).

2. Knowing the carbon content of the steel, determine I.H. from Fig. 1.

3. Having found the $D_1$ value, determine the I.H./D.H. values for the various distances on the Jominy test piece from Fig. 2.

4. Having determined I.H. and I.H./D.H. calculate the D.H. for various distances on the Jominy test piece by dividing the I.H. value by the I.H./D.H.

**Table I — Data on the NE Steels Studied**

| No. | Source | Grade | Grain Size | Analysis: C | Mn | Si | Ni | Cr | Mo | Diameter $D_1$: Actual | Cr Corrected |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bethlehem | NE9430 | 7 | 0.32 | 1.34 | 0.43 | 0.31 | 0.37 | 0.09 | 3.76 | .... |
| 2 | A.I.S.I. No. 8 | NE9440 | 7* | 0.41 | 0.90 | 0.57 | 0.37 | 0.31 | 0.15 | 3.66 | .... |
| 3 | A.I.S.I. No. 8 | NE9540 | 7* | 0.41 | 1.38 | 0.59 | 0.31 | 0.53 | 0.17 | 6.70 | 6.05 |
| 4 | A.I.S.I. No. 5 | A1340 | 7* | 0.40 | 1.77 | 0.19 | 0.10 | 0.08 | 0.02 | 2.19 | .... |
| 5 | A.I.S.I. No. 8 | NE9630 | 7* | 0.31 | 1.47 | 0.50 | 0.03 | 0.52 | 0.00 | 3.48 | .... |
| 6 | A.I.S.I. No. 8 | NE9640 | 8* | 0.38 | 1.48 | 0.55 | 0.03 | 0.56 | 0.01 | 3.85 | .... |
| 16 | A.I.S.I. Sheet 18 | NE8630 | 8* | 0.34 | 0.88 | 0.33 | 0.54 | 0.51 | 0.22 | 4.14 | 3.73 |
| 17 | A.I.S.I. Sheet 16 | NE8630 | 7* | 0.33 | 0.87 | 0.28 | 0.48 | 0.50 | 0.20 | 4.00 | 3.64 |
| 18 | A.I.S.I. Sheet 131 | NE8630 | 6 | 0.33 | 0.88 | 0.28* | 0.56 | 0.57 | 0.25 | 5.22 | 4.62 |
| 19 | A.I.S.I. Sheet 131 | NE8630 | 7 | 0.29 | 0.82 | 0.28* | 0.50 | 0.52 | 0.21 | 3.66 | 3.30 |
| 20 | A.I.S.I. Sheet 131 | NE8630 | 8 | 0.27 | 0.78 | 0.28* | 0.40 | 0.47 | 0.18 | 2.69 | 2.46 |
| 21 | Unknown | NE8720 | 7* | 0.20 | 0.75 | 0.24 | 0.58 | 0.42 | 0.27 | 2.98 | 2.78 |
| 22 | A.I.S.I. Sheet 120 | NE8720 | 8 | 0.19 | 0.73 | 0.25* | 0.60 | 0.45 | 0.32 | 2.70 | 2.49 |

*Grain size not recorded; estimated from collateral evidence.

The following specific example is offered for a heat of NE8339:

1. *Calculation of "ideal critical diameter"* ($D_1$)

| Element | Per Cent | Factor |
|---|---|---|
| C | 0.38 (No. 7 grain size) | 0.209 |
| Mn | 1.41 | 5.68 |
| Si | 0.28 | 1.25 |
| Ni | 0.09 | 1.03 |
| Cr | 0.06 | 1.16 |
| Mo | 0.25 | 1.78 |

$$0.209 \times 5.68 \times 1.25 \times 1.03 \times 1.16 \times 1.78 = 3.15\ (D_1)$$

2. *Calculation of initial hardness (I.H.)*

From Fig. 1, 0.38% carbon is equivalent to an initial hardness of C-56.

3. *Calculation of points on Jominy curve*

From Fig. 2, take out points corresponding to the horizontal ordinate for 3.15 I.D., and compute:

| Distance | I.H./D.H. | Computed Rockwell C | Actual |
|---|---|---|---|
| ¼ in. | 1.10 | 56 ÷ 1.10 = 51 | 53 |
| ½ | 1.36 | 56 ÷ 1.36 = 41 | 41.5 |
| ¾ | 1.62 | 56 ÷ 1.62 = 35 | 35 |
| 1 | 1.90 | 56 ÷ 1.90 = 29.5 | 31.5 |
| 1¼ | 2.06 | 56 ÷ 2.06 = 27 | 29.5 |
| 1½ | 2.18 | 56 ÷ 2.18 = 26 | 28 |
| 1¾ | 2.23 | 56 ÷ 2.23 = 25 | 27 |
| 2 | 2.30 | 56 ÷ 2.30 = 24 | 27 |

## *Reliability of Results*

The proposed method has been checked against Jominy tests from 43 different heats of various grades of steel. In the majority of cases, the calculations have been found to show a grain size of 7 at a quenching temperature of 1550° F.

Chromium and molybdenum contents of several of the heats were beyond the range shown for these elements on Grossmann's charts. In order to calculate $D_1$, the factor for these elements was determined by projecting the curves beyond their present limits. The results obtained fully justified this step.

**Table II — Calculated Points on Jominy End-Quench Curve**
*(Actual Values and Average Deviations in Italic)*

| No. | 1/16 In. | ¼ In. | ½ In. | ¾ In. | 1 In. | 1¼ In. | 1½ In. | 1¾ In. | 2 In. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 51, *51* | 48.5, *49* | 41.5, *39* | 35, *33* | 30.5, *30* | 28, *28.5* | 27, *28* | 26, *28* | 25.5, *28* |
| 2 | 56, *55* | 53, *54* | 44.5, *41* | 38, *35* | 33, *32* | 30, *31* | 29, *30* | 28, *30* | 27, *30* |
| 3 | 58, *58* | 58, *58* | 58, *56* | 56, *54* | 54.5, *52* | 53, *51* | 52, *51* | 50.5, *51* | 49, *51* |
| 4 | 57, *58* | 47, *52* | 33, *38* | 28, *31* | 24, *28* | 22, *26* | 21, *25* | 20, *24* | 20, *23* |
| 5 | 52, *52* | 48.5, *49.5* | 40.5, *40.5* | 34, *34* | 30, *30* | 27, *28* | 26, *25* | 25, *22.5* | 24.5, *20* |
| 6 | 56, *57* | 53, *54* | 46, *49* | 39, *41* | 33.5, *36* | 31, *33* | 30, *30* | 29, *27* | 28, *24* |
| 16 | 54, *52.5* | 49.5, *48.5* | 42, *35* | 36, *31* | 31, *29.5* | 28.5, *28* | 27, *27* | 26.5, *26.5* | 26, *26* |
| 17 | 52, *54* | 49, *52* | 41.5, *47.5* | 35, *36* | 30, *31* | 27.5, *29* | 26.5, *27* | 26, *26* | 25, *24.5* |
| 18 | 53, *51* | 52.5, *48* | 47.5, *38* | 42, *33.5* | 37.5, *31.5* | 35, *28.5* | 33, *27* | 32, *27* | 31, *27* |
| 19 | 51, *49* | 47, *45* | 39, *33* | 32, *28* | 28, *26* | 25.5, *25* | 24.5, *24* | 24, *23* | 23, *22* |
| 20 | 50, *46* | 43, *40* | 32, *28* | 26, *25* | 23, *23* | 21, *22* | 20, *21* | 19, *20* | 19, *19* |
| 21 | 46, *44* | 40.5, *38* | 31.5, *28* | 26, *23* | 22, *21* | 21, *20* | 19.5, *19* | 19, *18* | 18.5, *17* |
| 22 | 45.5, *46* | 38.5, *35* | 28.5, *25* | 24, *21* | 20, *19* | 19, *16.5* | 18, *16* | 17, *16* | 17, *15* |
| Dev. | *−0.7* | *−0.3* | *−2.1* | *−2.0* | *−0.6* | *−0.2* | *−0.3* | *−0.2* | *−0.5* |

favorable agreement with the actual test results. Tables I and II contain results for those now on the NE list. Below are average deviations at various points along the experimental curve, and Fig. 4 is a distribution curve showing the frequency of the deviations for the computations on all the 43 heats (including those shown in the table).

| Distance From Quenched End | Deviation (Rockwell Points) |
|---|---|
| 1/16 in. | 1.2 |
| ¼ | 1.6 |
| ½ | 2.8 |
| ¾ | 2.5 |
| 1 | 2.2 |
| 1¼ | 1.9 |
| 1½ | 1.7 |
| 1¾ | 1.8 |
| 2 | 2.0 |

It was usually impossible to obtain the austenitic grain size at the temperatures used in quenching these test pieces. It was therefore necessary to select fine-grained steels, as evidenced by the McQuaid-Ehn grain size, and to estimate the grain size which would probably be produced at the actual quenching temperature. For example, if the McQuaid-Ehn grain size (at 1700° F.) was given as 6 to 8 for a particular grade, it was reasonable to assume

In conclusion it may be said that a comparison of the predicted Jominy curves with actual Jominy results on 43 alloy steels indicates that the proposed method provides a means of making reasonably accurate hardenability predictions from composition and grain size. However, it is recognized that accumulation of sufficient data may well warrant adjustments in the method to provide increased accuracy. For example, the predicted values for NE8630 steels in Table II around ½ in. from the end are not at all good.

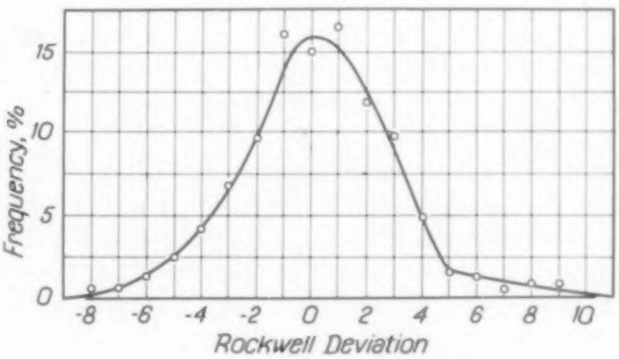



*Fig. 4 — Distribution Curve Showing Deviation of All Calculated Points From Actual Test Results on 43 Heats of Low Alloy Steels*

By Carter S. Cole
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*Conservation Division, W.P.B.*

# Down-Grading Chart *for* Brasses and Bronzes

WHEN COPPER, tin and other metals were cut off from their civilian uses some of the normal channels in which these materials regularly flowed were closed. As a consequence lower grades of secondary material are relatively much more available than primary metals. Brass mill scrap, on the other hand, has been routed back to the brass mills for reprocessing. In normal times, copper clippings and similar high purity scrap were used to sweeten, or up-grade, casting alloys. So the ingot makers and the foundrymen have had to work with materials having higher impurities than those to which they were accustomed. These broad trends were clearly pointed out in a memorandum prepared over a year ago for War Production Board by the Editor of *Metal Progress*, and published in this journal in June, July and August 1942.

In the meantime numerous "L" and "M Orders" have shut off copper, tin and other scarce materials from non-essential civilian purposes. Even with this, taking the picture as a whole and more specifically referring to the primary metals, we do not at the present date have sufficient for our direct and indirect military needs and for items directly concerned with health and safety.

To meet this emergency it is necessary to conserve scarce metals that are being used needlessly in places where a less critical substitute would serve. Real conservation can be achieved by a critical engineering examination of the end uses of all these alloys, then changing the specifications when this can be done. The primary objective is a better utilization of available material for maximum efficiency in the war effort. Fortunately a great mass of metallurgical data and generally improved foundry and mill operations are available as a basis for such necessary changes from easy or traditional practices.

In this connection specifications have been carefully reviewed by Army, Navy and Federal Specification Committees, the American Society for Testing Materials, and the Society of Automotive Engineers. Others, too, have cooperated, including many of our largest industrial companies which write their own specifications. In liberalizing specifications, requirements for virgin metal have been removed, impurity limits have been raised, and specifications for new alloys written so that material currently available could be used to better advantage.

The materials engineer has thus given the designing engineer the tools with which he may work. It is the designing engineer's responsibility from here on to make use of these tools in the most effective manner possible. The accompanying chart can serve as his guide and the table above it gives a ready cross-reference to specifications which are approximately equivalent.

The chart shows most of the important specifications grouped in columns according to the material required by an ingot maker or foundryman. Four classifications are given.

**Approximately Equivalent Specifications**

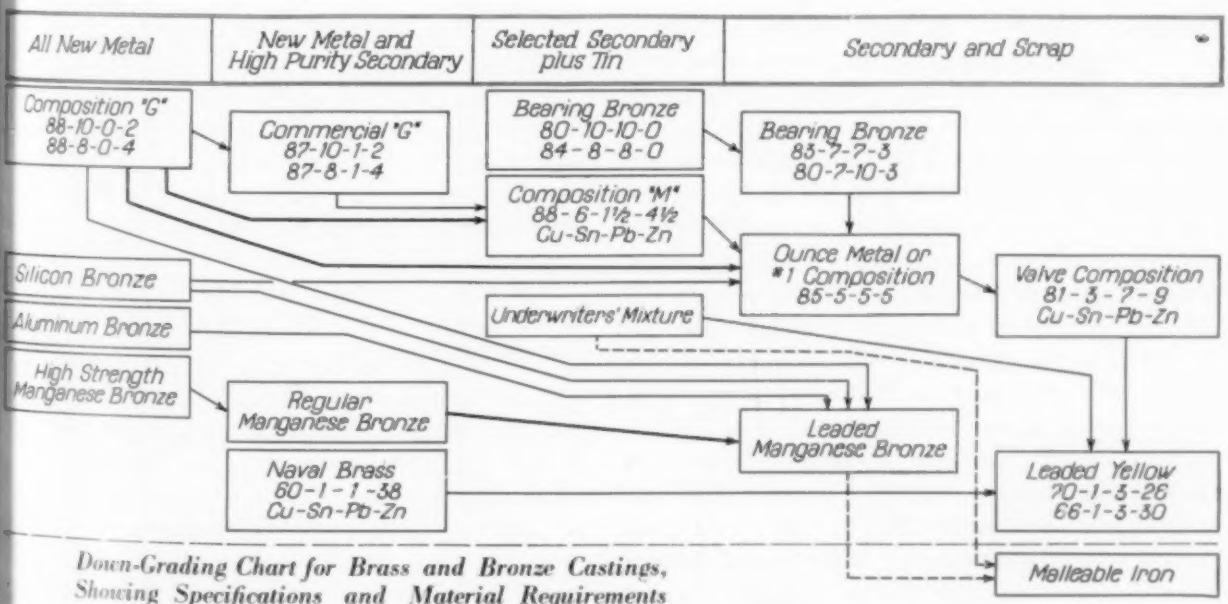
| Alloy | Specifications★ | | | | |
|---|---|---|---|---|---|
| | A.S.T.M. | Army & Federal | Navy | A.M.S. | S.A.E. |
| Composition "G" | B143, 1A & 1B; B 60 | QQ-B-691a-5 | 46M-6g "G" | 4845-A | 62 |
| Commercial "G" | B143, 2B; E-B143, 2X | QQ-B-691a-6 | 46B-5h "P-c" | | |
| Composition "M" | B143, 2A; B 61 | QQ-B-691a-1 | 46B-8g "M" | | |
| 85-5-5-5 | B145, 4A; B 62 | QQ-B-691a-2 | 46B23c "Oz-c" | | 40 |
| 81-3-7-9 | B145, 5A | QQ-B-691a-11 | 46B24d | | |
| 80-10-10 | B144, 3A | | | 4842 | 64 |
| 84- 8- 8 | E-B144, 3Y | QQ-B-691a-8 | 46B22d "II" | | |
| 83- 7- 7-3 | B144, 3B | QQ-B-691a-12 | | | 660 |
| 80- 7-10-3 | E-B144, 3X | | | | |
| Naval brass | B146, 6C | QQ-B-621-A | 46B10f "N-c" | | |
| 70- 1- 3-26 | B146, 6A; E-B146, 6X & 6Y | E-QQ-B-621-X & Y | 46B11 (INT) | | |
| 66- 1- 3-30 | B146, 6B | QQ-B-621-B | 46B11f (INT) | | 41 |
| Silicon bronze | | QQ-C-593 | 46B28 (INT) | | |
| Aluminum bronze | B148, 9A & 9B | QQ-B-671a | 46B18c | | 68 |
| Underwriters' mixture | | WW-C-621a | 34F-3c | | |
| H. S. manganese | B147, 8B | QQ-B-726b-B & C | 46B29 "MA-c" | 4862 | |
| Regular manganese | B147, 8A | QQ-B-726b-A | 49B-3e "Mn-c" | 4860 | 43 |
| Leaded manganese | B147, 7A | QQ-B-726b-D | | | |

★Specifications, as shown, are approximately equivalent but may not in all cases be interchangeable for procurement and inspection.

"All New Metal" includes No. 1 and No. 2 copper as well as electrolytic. "High Purity Secondary" is exemplified by such items as fired cartridge cases currently used to make regular manganese bronze. In any specification where the lead is equal to or greater than the tin, the tin content of bronzes can generally be introduced from secondary sources such as sweated radiator cores. (Lead is generally the contamination of our secondary supply that restricts its use in tighter specifications.)

Such, in general, are the considerations governing our supply of materials to make the various grades of brass and bronze castings.

The designer, in the past, has given little or no thought to conservation but has specified what he believed to be the best material for




*Down-Grading Chart for Brass and Bronze Castings, Showing Specifications and Material Requirements*

the purpose intended. For example, composition "G", or gun metal, has many important and traditional uses. When our supply of raw materials was unrestricted there could be little criticism of a designer who specified this excellent bronze for varied uses. Today, however, the 0.2 or 0.3% lead max. in its specification requires primary copper and tin.

Now the designer must revise his thinking, about gun metal, and specify the least restrictive material that will do the work at hand. As indicated on the chart, in many instances composition "M", or even 85-5-5-5 will give adequate service performances for many items where composition "G" has been specified. The armed services are recognizing this and have changed many specifications to conserve primary metal. The Navy, for instance, last spring issued a directive permitting the use of composition "M" in place of composition "G" in pressure castings. Again, the Maritime Commission has changed propeller shaft sleeves from "G" to "M", an alloy on which the Navy had standardized for this purpose.

More recently the Navy has pointed out the possibilities of substituting 85-5-5-5 for composition "M", composition "G" or silicon bronze for sea water valves and fittings. It might also be noted that, where structural strength is the primary consideration, leaded manganese bronze is an excellent choice in place of composition "G", silicon bronze or aluminum bronze.

There are times, of course, when a partial or full substitution of ferrous metal may be made for some of the non-ferrous alloys — even in some uses connected with our war effort. Such, for instance, is the current use of malleable iron tail-pieces for fire hose couplings that formerly were made of the Underwriters' mixture. Swivels and couplings used aboard ship are retained in a non-ferrous metal; the alloy used, however, is a common leaded yellow brass that can be made entirely from secondary material. Other possible design changes are shown on the chart. Those which are currently most desirable are indicated by the heavier connecting lines.

Results of the conservation efforts have been very encouraging. Much more still remains to be done. It is work in which all who are connected with the war effort can cooperate.

# Conservation of Metals in Cannery Machines

In line with the changes in materials suggested by Mr. Cole in the preceding article, an Advisory Committee to W.P.B. for the Food Processing Machinery Industry and the U.S. Department of Agriculture recommend the following changes in new machinery which will not curtail their utility:

1. Use no magnesium, aluminum, cadmium, nickel (unless required for pineapple screens).

2. Copper is to be used only in *(a)* copper steam-jacketed kettles, *(b)* cooking coils, *(c)* finisher, pulper and extractor screens, *(d)* grading screens for acidulous fruits, *(e)* tubing for tomato products.

3. Tin is to be used only for plating and to be restricted to parts that come into actual contact with food.

4. Bronze is to be used for bearings, gears, valves, and fittings; parts contacting corrosive glues in labeling and sealing machines; parts of fruit or vegetable pulpers, juice extractors and finishers that come in contact with the food product; and bearings and packing glands in fresh fruit and vegetable grading, packing and treatment equipment.

5. The use of copper base alloys (brass) should be restricted to the following: *(a)* Sheets for hoppers, pans, covers, screens for finishers, pulpers and extractors; *(b)* bars for shafting in similar machinery; *(c)* tubing for sheathing shafts and rolls; *(d)* rods in fillers, pulpers, finishers and extractors.

6. Stainless steel to be used only in *(a)* operating equipment for citrus products, pineapple, and mayonnaise; *(b)* cutting knives for mechanical slicing or dicing; *(c)* heating tanks and coils for citrus products, pineapple, tomato juice, vinegar products, sauerkraut, and chicken.

7. Monel metal is to be restricted to bolts and other fasteners for fresh fruit and vegetable treating equipment.

8. Use only secondary metal for copper-nickel alloys for *(a)* filling chambers, valves, and pump parts for baby foods, citrus, pineapple and milk products; *(b)* pump parts in contact with hydrochloric solutions.

9. Alloy steels to be restricted to National Emergency steels and then used only for knives, gears and clutches.

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# Weldability of NE 1330 and NE 1335 (Laboratory Tests)

Harder and Voldrich in a paper entitled "Weldability of Carbon-Manganese Steel; Weld-Bead Hardness and Weld-Bead Bend Test", published in *Welding Journal*, Oct. '42 sup. (Vol. VII, p. 450-s) by the Welding Research Committee of the Engineering Foundation, have discussed the effect of carbon and manganese on weldability, and have shown that there is a rather consistent relation between the maximum hardness produced in the weld-bead hardness tests and the "carbon equivalent" (the "carbon equivalent" is C + 1/6 Mn).

TO FURTHER a campaign of publicity about the "national emergency steels" the Editor of *Metal Progress* has asked for a brief comparison of the weldability of the S.A.E. steels 1030 and 1035, with the NE steels 1330 and 1335 with 1.60 to 1.90% manganese. Obviously, the interest in such a comparison is limited to those applications in which it is desired to utilize the higher strength possessed by the medium manganese steels.

Comparison of the analyses of these steels shows that they differ principally in manganese content, with the NE steels having a manganese content of 1.60 to 1.90% as contrasted with 0.60 to 0.90% for the S.A.E. steels. In addition, the specified carbon contents are in a narrower range, but the maxima in the NE steels are lower than the maxima for the S.A.E. steels. There is the further slight difference in the silicon content because both the minimum and the maximum silicon contents are 0.05% higher than in the NE steels. It appears, however, that the only significant difference in the composition with reference to weldability is the manganese content. It is, therefore, pertinent to look into the effect of manganese on the weldability of steels as shown by laboratory tests.

Data from this publication have been used to construct the accompanying graph. Some data available from other sources have also been added and the values are shown as open circles. These data have been limited to tests with 3-in. beads applied to ½-in. plates, with the original plate at ordinary laboratory temperatures such as 70 to 80° F.

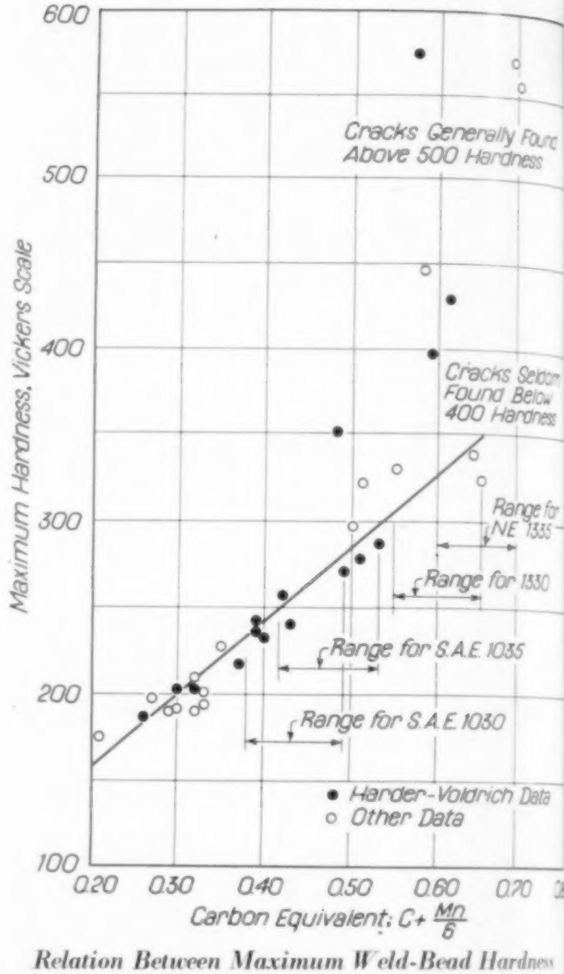
Examination of the accompanying figure shows that when the values for the maximum hardness are plotted as a function of the carbon equivalent, they fall reasonably close to a straight line up to a carbon equivalent of 0.50 to 0.60, and that the slope of a line drawn to represent these points is in the range of about 4 to 5 points on the Vickers scale for each 0.01 carbon equivalent. It is further shown that as the carbon equivalent increases beyond a value of about 0.50 to 0.60 hardnesses far above the extension of this straight line are encountered.

It appears then, under these particular testing conditions, that for carbon equivalents below about 0.50 the structure in the heat-affected metal under the bead is pearlitic, that as the carbon equivalent increases beyond 0.60 martensite is encountered, and finally the structure becomes fully martensitic and high hardnesses of the order of 500 Vickers are

encountered. It is, therefore, obvious that increasing manganese in steel of fixed carbon content raises the carbon equivalent and increases the probability that it falls in the group which develops these high hardnesses.

Harder and Voldrich also found that cracks in weld-bead hardness specimens were rarely found below Vickers hardnesses of 400, but were generally found when the hardness exceeded 500. They found that weld-bead bend tests were of questionable value in determining the weldability of steels, and showed that steels of the NE1330 and 1335 types passed this test although the maximum hardness was 400 or over. Increasing the plate thickness increases the maximum hardness developed in the weld-bead test, while decreasing the plate thickness decreases the maximum hardness. Interpreted in terms of the accompanying figure, increasing the plate thickness would increase the hardness in all carbon equivalents and furthermore decrease the carbon equivalent at which hardnesses well above the curve would be obtained. These relations would all be reversed by decreasing the plate thickness. Lowering the plate temperature has the same general effect as increasing the plate thickness, because that is another mechanism for increasing the cooling rate of the metal in the heat-affected zone. Evidently, raising the plate temperature would have the opposite effect and result in increasing the carbon equivalent which could be used without developing the high hardness values shown in the accompanying figure.

As a result of these tests it appears that a logical comparison of these steels is on the basis of the carbon equivalent. With the specified welding conditions there is danger of encountering high hardness in the heat-affected zone in welds in ½-in. plate, and the possibility of cracks therein when the carbon equivalent is above about 0.50.




*Relation Between Maximum Weld-Bead Hardness and "Carbon Equivalent" in Carbon-Manganese Steels (½-In. Plate at Room Temperature). Increasing plate thickness, decreasing its temperature, and decreasing diameter of electrode or length of weld move the curve upward — and vice versa*

Industry is familiar with the practice of preheating for welding in structures which are likely to give trouble, and the accompanying figure gives an indication of the relation of chemical composition to the hardnesses which may be encountered and therefore the relation of composition to the temperatures and plate thicknesses which may be used.

EDITOR'S FOOTNOTE: Test procedure was as follows: Samples of the plate were normalized and shot blasted. For weld-bead hardness tests a 6×12-in. piece was laid flat and a bead run down its centerline at 5 in. per min., using A.W.S. class E6010 all-purpose electrode, $\frac{3}{16}$ in. dia., 180 amp. direct current, 26 volts, electrode positive. The plate was then sawed at right angles to the bead, the section polished and lightly etched to show penetration. Hardness was surveyed by Vickers tests spaced 0.02 in. along a line parallel to the top face and tangent to the weld bead at its deepest penetration, and also along two inclined lines normal to the transition zone near the edges of the bead. The section was also examined at 20 diameters for cracks.

An attempt was also made to correlate the above with weld-bend tests. In this a 3×18-in. piece of plate had a bead 6 in. long run centrally, and ground down to the level of the base plate, then bent in A.W.S. standard test jig (welded bead in tension). Angle of bend, elongation around bend and load were recorded at the appearance of the first crack (if any; it is in the heat affected zone). "The general relation seems to be that steels which did not develop cracks under the beads in the weld-bead hardness tests did not fail in the weld-bend test."

# Critical Points

## By the Editor

LISTENING to Lt. Col. HAROLD TURNER tell the Society of Automotive Engineers' annual meeting about steel cartridge cases, and was proud of the American technologist, for it is undoubtedly true that successful cartridge cases have been and can be made of various steels by numerous processes, ranging from single pieces of heat treated alloy steel (provided it is clean and free of inclusions) to welded composites of steel screw-machine parts and brass tubing. In fact, four different methods are now in production, forming the all-important steel cup. Three of the four methods depend on the prior existence of commercial operations, and of plants containing the necessary machinery and "know how". Once the cup has been prepared to proper shape and accuracy, subsequent operations follow the cold drawing operations long known by brass manufacturers; the only new thing to be learned here is that one can use other steels than the soft steel deep-drawing fender stock. Medium carbon steels can be drawn almost as fast and as drastically as brass. This is of importance, for the correct *prompt* solution of the problem of duplicating brass cartridges in steel involves the use of the presses and other heavy machinery already existing and on order for making brass cases. About the only large difference is in the use of carbide drawing dies or rings; whereas hardened alloy steels work well on brass, they wear rapidly and pick up particles of metal when drawing cold steel, thus going out of size and scratching the work. Finally, the corrosion problem has been solved in a way that has reacted favorably in other directions. Americans, as well as our enemies, use a strong phenolic "plastic" that bakes on hard and tight — so tight that apparently its elastic properties modify usefully those of the steel it protects.

*Steel cartridges eke out our copper supply*

GUIDED by BOB McCLEARY (FRED McCLEARY'S son) through Chrysler's aluminum and steel forges, and that portion of the Plymouth plant now given to track details for medium tanks — parts that bulk more like pieces for locomotives than for automobiles. Much impressed by the smooth flow of aluminum through an orderly new forge plant, and assured by Superintendent CLEM HELLEBUSH that the best way to keep hammers busy is to have *ample* heating capacity. Double chamber furnaces (even triple chamber furnaces), heated with recirculated air, are the rule; one generous charge is therefore coming up to heat and soaking while the other is being fed to the hammer. Remarkably little clean-up labor by trimmers, grinders and sanders is necessary when the various stages (blockers and intermediate dies) are properly designed, step by step, to gather the metal where it is wanted, without attempting to form a shape in three stages when four will do it comfortably. Accurate sizing of blanks, careful trimming and cleaning of intermediate shapes, and thoroughly uniform heating also sa[illegible] bor in the cleaning department....One unconventional practice noted is the conversion of a cylindrical slug into a shape like an electric light bulb by forcing it down into a closed die, and blowing it out with compressed air on the upstroke of the punch. There's no flash to worry about.

*Ample furnace capacity for aluminum forge shop*

OBSERVED a neat machine for flame hardening teeth on the main sprockets for tank-tracks. This part starts as a ring-shaped forging of carbon-molybdenum S.A.E. 4047 steel, about 30 in. diameter by 1½ in. thick, and is completely machined before heat treating. At the beginning of the cycle, a sprocket, flat on its

face, is elevated into a concentric ring of small gas-air burners, a pair of opposing flames being directed against each tooth, striking well down toward the pitch line, and heating tooth ends and wearing surfaces to full red by the flaring flame and by conduction, to a depth of ¼ in. The elevator then lowers, and the sprocket is kicked forward down an inclined roller table into a water quench. A 3-hr. stress relief at 380° F. completes the job except for shotblasting to clean off scale; this also clearly demarks the depth of hardening. Rockwell limits are C-50 to 55. . . . Some of the rectangular quenching tanks in this department have especially violent oil circulation. In two corners are placed 12-in., 3-bladed propellers, driven by 10-hp. motors, which force the oil violently toward the opposite center where it strikes a small submerged weir. It looks like water boiling down the rapids of a mountain stream. This, with wetting agents added to the oil, gives an unusually good quench, and has rescued an intricate part made of S.A.E. 4047 which normally would have been specified 15 points higher in carbon. It is also very good for steels conforming to specification but on the low side of hardenability.

***Flame hardener***

***Improving the oil quench***

RECALLED many amusing incidents of a brief tour of duty 25 years ago at University of Cincinnati, in company with ANDY LANGHAMMER, then one of my students, now president of Chrysler's Amplex Division, where bearings and machine parts by the million are made of powdered iron, copper, bronze and brass in various combinations. The department began about 15 years ago, when ANDY first tried to improve water pump bearings, an automobile part that traditionally had given the most trouble. Development since then has been continuous, not only in quality, but in diversity of application and maximum permissible sizes which are now astonishing. Ball bearing retainer rings 20 in. in diameter — 12-in. sleeve bearings, 8 in. long — plates and slides weighing 60 lb. each — disks 24 in. diameter — solid bars 7 in. diameter by 6½ in. long — such relatively enormous parts would seemingly require relatively enormous presses and pressures, but after breaking the biggest pressframe in the shop finesse replaced brawn. Notable also are the strength and rigidity of dies, punches and mountings — all essential for final accuracy. . . . The first requirements in Amplex' early days were for porous, oil-sponge bushings, and material of this nature is still the division's biggest output. However, compactness and strength have been steadily improved until now 100 parts are made for a single anti-aircraft gun and its mounting, and are ideally suited for motion under inadequate lubrication — a vital contribution to ordnance that must work at +200 to −70° F. Another indication of vastly improved strength of powder metal parts is the production of balls and rollers for universal joints and substitutes for mechanical bearings, breaking a bottleneck in parts needed for aircraft and mobile units.

***Powder metal compacts of large size***

Quick production of intricate parts has also eased many a tight situation caused by a lack of broaches, cutting tools and machine tool capacity. Pieces with blind holes, square or hexagon, are especially difficult to machine, but "duck soup" for powder compacts. In one hurry-up order the dies were cut for a gun sight and the part was in production 30 hr. after the order was received. . . . Auto parts have also been adapted to war needs; notably the Chrysler "Gerotor" pump for hydraulic mechanisms and oil pumps — a four-toothed impeller rotating within a five-vaned casing, difficult to machine, easy to mold. With a rubber lining for the casing this becomes an efficient bilge pump that can't be fouled by bullets, shell fragments or other solids sucked in with the water. . . . All the arguments for die casting, such as economy of material, accurate dimensions, and minimum of machining, hold for a powder metal compact, and in addition all composition limits are removed, and probably strength and ductility limits as well. At any rate, I saw rotating bands for 20-mm. shell (pressed from powdered copper) that could be closed flat without fracture. Other interesting but "classified" parts are in production which take advantage of the unique and controllable properties of metallic sponges, such as lower mass (inertia) and low magnetic losses and of composites — part brass, part steel.

***Ordnance parts with unique properties***

# Properties of Important Wrought Chromium-Nickel-Iron Alloys

*Revised 1943, from data furnished by U.S. Steel Corp., Electro Metallurgical Co., and Commitee A-10, A.S.T.M.*

| Nominal Alloy A.I.S.I. Type No. | 18-8 302† | 18-8 Ti 321 | 18-8 Cb 347 | 18-12 Mo 316 | 20-12 308 | 24-12 309 | 25-20 310 | 18-26 311 |
|---|---|---|---|---|---|---|---|---|
| **Chemical composition** | | | | | | | | |
| Chromium | 17 to 19 | 17 to 19 | 17 to 19 | 16 to 18 | 19-22 | 22 to 24 | 24 to 26 | 18 to 20 |
| Nickel | 8 to 10†† | 8 to 11 | 9 to 12 | 10 to 14 | 10-12 | 12 to 15 | 19 to 22 | 24 to 26 |
| Mn (max.) | 1.25 | 2.00 | 2.00 | 2.50 | 2.00 | 2.00 | 2.00 max | 2.00 max |
| Carbon | 0.08 to 0.20 | 0.10 max | 0.10 max. | 0.10 max. | 0.10 (max) | 0.20 max. | 0.25 max. | 0.25 max. |
| Others | — | Ti 4 x C | Cb 10 x C | 2 to 3 Mo | — | — | — | — |
| **Specific gravity** | | | | | | | | |
| Lb per cu. in. | 0.288 | 0.286 | 0.29 | 0.291 | 0.287 | 0.29 | 0.285 | 0.280 |
| (Mild steel = 1.00) | 1.02 | 1.01 | 1.02 | 1.03 | 1.01 | 1.01 | 1.01 | 0.99 |
| **Electrical resistance at 70°F.** | | | | | | | | |
| Microhm per cm.³ | 72 * | 72 | 73 | 74 | — | 78 | 80 ± | 102 |
| (Mild steel = 1.00) | 6.6 | 6.6 | 6.7 | 6.8 | — | 7.1 | 7.3 | 9.3 |
| **Melting range, °F.** | | | | | | | | |
| Top | 2590 | 2600 | | 2550 | 2590 | 2650 | 2650 | — |
| Bottom | 2550 | 2550 | | 2500 | 2550 | 2550 | 2550 | — |
| **Structure** | Austenitic | Austenitic | | Austenitic | Austenitic | Austenitic | Austenitic | |
| **Magnetism** | | | | | | | | |
| Ferromagnetic | — | — | — | — | — | — | Trace | — |
| Permeability – As annealed | 1.003 | 1.003 | 1.02 | 1.003 | — | 1.003 | 1.003 | — |
| Permeability – Cold Worked | 1.10 to 7.0 | — | — | 1.10 to 10.0 | — | — | — | — |
| **Specific heat** | | | | | | | | |
| C.g.s. units, 0 to 100°C. | 0.12 | 0.12 | | 0.12 | — | 0.12 | 0.14 | — |
| (Mild steel = 1.00) | 1.1 | 1.1 | | 1.1 | — | 1.1 | 1.3 | — |
| **Thermal conductivity** | | | | | | | | |
| ** C.g.s. units at 100°C. | 0.0388 | 0.0385 | | 0.0372 | 0.039 | 0.03 to 0.04 | 0.0330 | — |
| (Mild steel = 1.00) | 0.33 | 0.32 | | 0.316 | 0.33 | 0.25 to 0.35 | 0.280 | — |
| C.g.s. units at 500°C. | 0.0512 | 0.0528 | | 0.0499 | — | — | 0.0413 | — |
| **Thermal expansion per °F x 1,000,000** | | | | | | | | |
| From 32 to 212°F. | 9.5 | 9.3 | | 8.9 | 9.6 | 8.3 | 8.0 | 8.8 |
| (Mild steel = 1.00) | 1.44 | 1.40 | | 1.35 | 1.45 | 1.26 | 1.21 | 1.33 |
| From 32 to 932°F. | 10.2 | 10.2 | | 9.7 | — | 9.6 | 9.2 | 9.3 |

| Mechanical Properties at Room Temperature | Annealed | Cold Worked (Type 301X)† | Annealed | Annealed | Cold Worked | Annealed | Annealed | Cold Worked | Annealed | Annealed |
|---|---|---|---|---|---|---|---|---|---|---|
| Tensile strength, 1000 psi. | 80 to 100 | 150 to 300 | 75 to 95 | 80 to 95 | 140 to 200 | 70 to 90 | 90 to 100 | 110 to 270 | 80 to 110 | 90 to 110 |
| Yield strength, 1000 psi. | 30 to 45 | 130 to 275 | 30 to 45 | 35 | 120 to 180 | 30 to 60 | 40 | 65 to 230 | 35 to 55 | 45 to 50 |
| Elastic modulus, $10^6$ psi. | 28 | 26 to 28 | 29 | 28 | — | 28 | 29 | — | 30 | 30 ± |
| Elongation, % in 2 in. | 65 to 45 | 20 to 2 | 60 to 45 | 65 to 50 | 18 to 6 | 75 to 50 | 55 to 35 | 15 to 3 | 60 to 45 | 35 to 30 |
| Reduction of area, % | 70 to 50 | 55 to 10 | 65 to 50 | 70 to 55 | 65 | 70 to 45 | 60 to 50 | 55 to 20 | 60 to 50 | 45 to 35 |
| Impact, ft-lb.; Charpy | 90 to 60 | — | 80 | 80 | — | — | 90 to 60 | — | 80 to 70 | — |
| Izod | 110 to 75 | 50 to 20 | 100 | 100 | — | — | — | — | 100 to 60 | 50 to 90 |
| Fatigue endurance limit, 1000 psi. | 30 to 40 | 85 | 45 | 39 | — | — | 42 | — | — | — |
| Hardness, Brinell | 150 to 160 | 365 to 410 | 135 to 149 | 135 to 165 | — | 135 to 185 | 150 to 185 | 170 to 375 | 160 | 160 to 185 |
| Rockwell | B-75 to 80 | C-36 to 50 | B-75 | B-75 to 90 | C-30 to 38 | — | B-80 to 90 | C-5 to 40 | B-80 | — |
| Erichsen value, mm. | 10 to 14 | — | 12 | 12 | — | — | 7 to 8 | — | — | — |

| Stress in psi. causing 1% "creep" in 10,000 hr. at | Annealed | Cold Worked (Type 301X) | 321 | 347 | Annealed | Cold Worked | Annealed | Annealed | Cold Worked | Annealed | Annealed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000°F. | 17,000 | | 18,000 | 19,000 | 23,000 | | | 17,000 | | 17,000 | 17,000 |
| 1200 | 7,000 | | 7,800 | 9,500 | 10,000 | | | 8,500 | | 9,000 | — |
| 1350 | 2,500 | | 3,600 | 4,000 | 5,500 | | | 3,500 | | 3,300 | — |
| 1500 | 850 | | 850 | — | 2,000 | | | 1,000 | | 1,100 | — |
| 1600 | — | | — | — | — | | | — | | — | 1,900 |

| | 18-8 302 | 18-8 Ti 321 / 18-8 Cb 347 | 18-12 Mo 316 | 20-12 308 | 24-12 309 | 25-20 310 | 18-26 311 |
|---|---|---|---|---|---|---|---|
| Scaling temp., °F. | 1650 | 1650 | 1650 | 1650 | 2000 | 2000 | 1650 |
| Initial forging temp., °F. | 2000 to 2200 | 2100 to 2200 | 2100 to 2200 | — | 2000 to 2150 | 2000 to 2150 | 2050 |
| Finishing temp., °F. | Not under 1700 | Same as 18-8 | As for 18-8 | — | Not under 1800 | 1800 to 1850 | 1700 |
| Annealing treatment | Heat at 1950 to 2050°F. and Quench | Same as 18-8 | 1950 to 2050 °F. and Quench | — | Heat at 2000 to 2100°F. and Quench | Same as for 24-12 | 2000° (Quick Heat & Quench) |

* Electrical resistance of cold worked 18–8 ranges from 70 to 82 microhms per cm cube

** Thermal conductivity is measured as calories per sq. cm. per sec. per °C per cm.

† Type 301X is the cold-worked sheet for light weight structure

†† For spinning purposes Ni is sometimes specified 10 to 12 %


NICKEL
INCO

By Edward C. Bishop
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and Morris Cohen
*Massachusetts Institute of Technology*

# Hardness Testing of High Speed Steel at High Temperatures

SINCE the industrial importance of high speed steel is attributable to its capacity for retaining excellent cutting qualities at elevated temperature, its hot-hardness has received, and still deserves, considerable attention. As long ago as 1933 Harder and Grove have shown in *Transactions* A.I.M.E. that there is a reasonably good correlation between the high temperature hardness and the cutting efficiency of high speed lathe tools. Similar indications have been reported by Emmons in a discussion of that paper; he used drill tests for evaluating tool performance. Hence, hot-hardness measurements seem to offer a convenient basis for comparing, at least in a preliminary way, the cutting potentialities of the different types of high speed steel. This is particularly appropriate at the present time when substitutions are the order of the day.

Although it is generally overlooked, hot-hardness testing can also be employed advantageously for tracing the course of structural phenomena while they are taking place. Unquestionably, hardness determinations at room temperature have proved very helpful in the study of such physical changes as austenite decomposition, tempering reactions, and age hardening; yet these measurements, like so many other tests at room temperature, are affected not only by the transformation in question, but also by possible changes during the cooling to room temperature. Quenching does not always avoid such extraneous effects and, in many cases, introduces the further variable of internal stress. Moreover, the obscure dependence of hardness on temperature also tends to complicate the relationship between the *extent* of transformation at some elevated temperature and the *hardness* of the composite structure after cooling to room temperature.

It is evident that these difficulties may be entirely circumvented by making the hardness determinations *at temperature* while the structural changes are in progress. However, this application of hot-hardness measurements calls for the maximum of precision, flexibility and control. The type of measurement to be described here fulfills these requirements, and has been used successfully to follow the tempering of high speed steel as well as to compare the hot-hardness of several grades after the usual commercial treatments.

A Rockwell machine determines the "at temperature" hardness of a specimen or specimens in a specially designed furnace; thus, the hardness values are obtained directly in C-scale units, without questionable conversions and without cooling the samples even for measuring the impressions. Because of the small size of the impressions, many readings may be taken on a single sample; normal precision of the Rockwell method is attained by providing a non-scaling atmosphere. During runs, the indenter is heated in the furnace, along with the specimens, to the exact temperature of the sample whose hardness is to be measured. Furnace and specimens are movable with respect to the indenter without affecting the controlled atmosphere, and the impressions may be accurately placed, since the indenter and specimens are observable at all times. In fact, hardness variations of a single sample may be readily followed through a complete cycle of heating to, holding at, and cooling from the reaction temperature.

Details are shown in the drawing on page 414. The indenter is a standard diamond Brale. The Rockwell machine should have at least 8-in. vertical capacity. By means of the holder or indenter extension, the diamond mounting extends into the furnace which, in turn, rests on the elevating base of the Rockwell machine. The upper end of the indenter assembly fastens into the hardness machine with the same set-screw fitting normally provided for holding the indenter.

A stainless steel tube, 2¼ in. inside diameter by 6 in. long, forms the muffle of the furnace, and is insulated from the chromel winding by mica tape. Specimens are supported in the furnace on an anvil, rigidly attached to the base plate of the furnace. The specimen and indenter are observed through two conical tubes welded into the side wall of the muffle; a small incandescent bulb at the end of one tube provides illumination. A third tube admits two thermocouples and the purified nitrogen atmosphere. Temperatures of indenter and specimen surface are read with two other thermocouples, disposed as indicated. The flanged furnace cover is permanently fixed to the indenter assembly, dips into a trough of oil, and provides considerable lateral and vertical movement to locate the hardness impression and to set the minor load. The major load is applied by the Rockwell machine in the usual way.

Water flowing through copper coils cools the oil seal and certain other joints. Parts of the Rockwell machine above the furnace are similarly cooled, particularly since the indenter holder is equipped with an auxiliary winding for counterbalancing heat losses and for securing an independent control over the temperature of the indenter, thus insuring against changes in the surface temperature of the specimen during the hardness measurement.

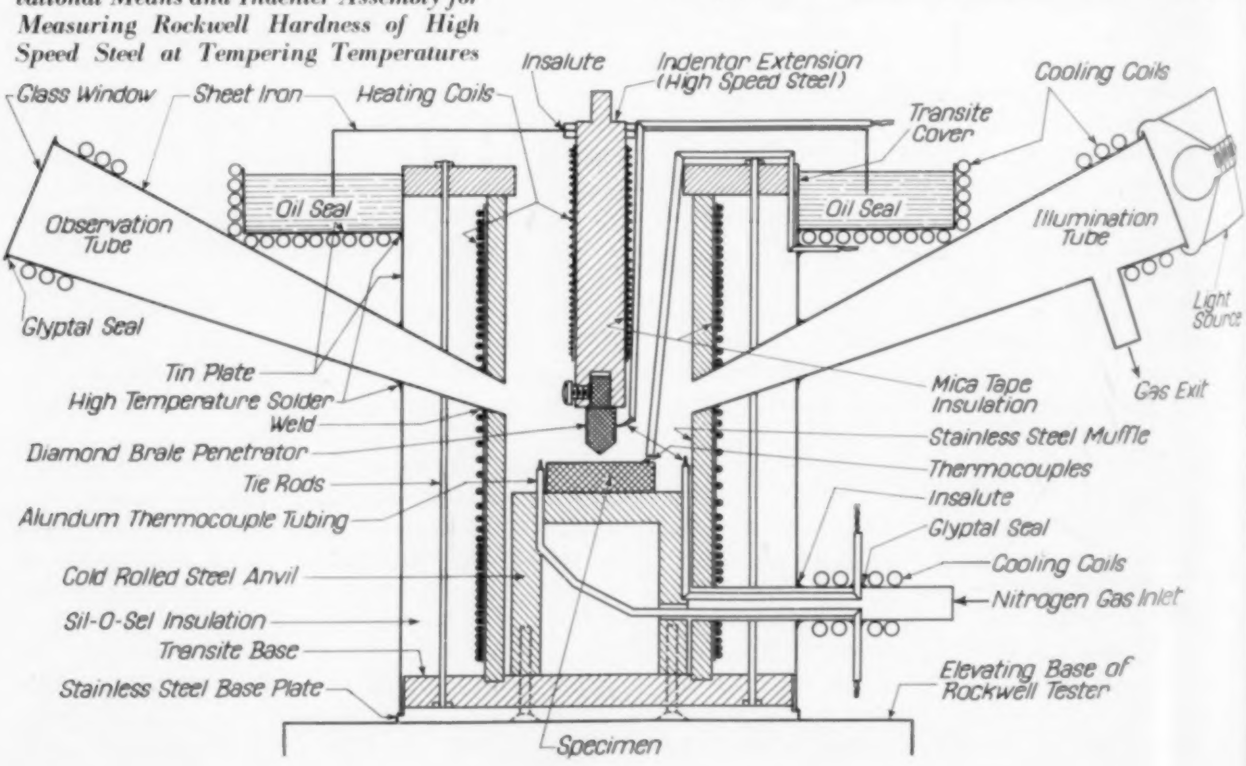
With this apparatus, as many as 40 to 50 separate hardness determinations during various heat treatment cycles may be obtained on a single steel sample 1½ in. long by ⅜ in. wide, without removing it from the furnace. Hardness readings may be taken "on the fly" while the sample is heating or cooling, but the results are more accurate if the changing temperature is momentarily halted. Temperatures are controllable to ± 2° F. by a temperature regulator activated by the thermocouple along the wall of the muffle, and the maximum temperature variation from end to end of the specimen is less than ± 5° F. Hardness readings are generally reproducible to within ± 0.5 point on the C scale, while the *relative* accuracy during a given run is even better.

The standard diamond Brale and its metal mounting seem to stand up well in the nitrogen atmosphere, at temperatures at least up to 1100° F. Higher temperatures may not cause undue deterioration of the indenter, but no studies have been made above 1100° F., since this apparatus was designed primarily for use in experiments on tempering.

## *Typical Results*

*Effect of Steel Composition* — Hot-hardness values at temperatures of 1000°, 1050°, and 1100° F. are shown in the table for eight grades of high speed steel. (Analyses and heat treatments are also given.) All samples were hardened by standard commercial treatments, and the tempering temperatures were adjusted to secure complete

*Sketch of Furnace, Thermocouples, Observational Means and Indenter Assembly for Measuring Rockwell Hardness of High Speed Steel at Tempering Temperatures*



**Commercial High Speed Steels Tested**

| Steel Type | Composition | | | | | | Heat Treatment | | Hardness at 70° | | | Hot-Hardness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | W | Mo | Cr | V | Co | Harden | Temper | Hardened | Tempered | At End (a) | 1000° F. | 1050° F. | 1100° F. |
| 14-4-1 | 0.71 | 14.60 | .... | 4.13 | 2.08 | .... | 2300° F. | 1050° F. | 66.0 | 64.0 | 63.3 | 58.0 | 56.5 | 54.5 |
| 18-4-1 | 0.72 | 18.16 | .... | 4.05 | 1.04 | .... | 2350 | 1050 | 66.0 | 65.2 | 64.8 | 58.3 | 57.2 | 55.8 |
| 18-4-2 | 0.835 | 18.52 | 0.65 | 4.24 | 2.12 | .... | 2350 | 1050 | 66.1 | 66.3 | 66.2 | 60.2 | 57.8 | 56.2 |
| W-5% Co | 0.725 | 17.29 | 0.52 | 4.00 | 1.06 | 4.73 | 2400 | 1050 | 65.0 | 66.2 | 65.8 | 60.2 | 59.5 | 58.7 |
| W-12% Co | 0.795 | 20.38 | 0.65 | 4.22 | 1.64 | 12.44 | 2375 | 1000 | 64.0 | 67.2 | 67.1 | 62.0 | 61.4 | 59.6 |
| 6-6-4-2 | 0.855 | 6.50 | 5.62 | 4.48 | 2.08 | .... | 2235 | 1050 | 65.1 | 65.3 | 64.8 | 58.0 | 57.2 | 55.9 |
| Mo-V | 0.845 | ... | 8.29 | 4.12 | 2.24 | .... | 2215 | 1025 | 64.9 | 65.3 | 64.8 | 58.0 | 57.0 | 55.5 |
| High C, high V | 1.275 | 5.71 | 4.47 | 4.44 | 4.15 | .... | 2220 | 1075 | 66.0 | 65.4 | 65.1 | 59.0 | 57.5 | 56.7 |

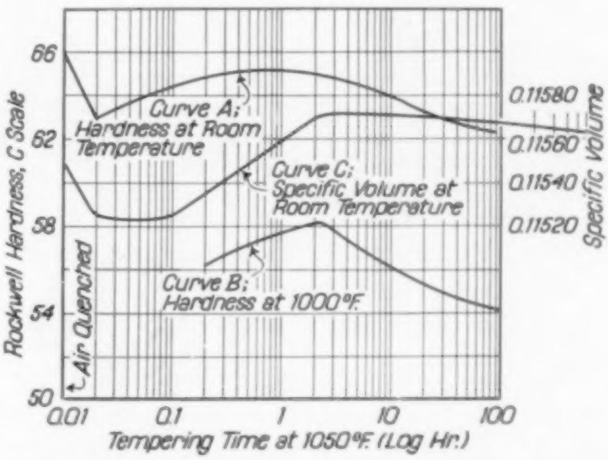
*(a)* After hot-hardness tests

decomposition of the retained austenite after a tempering time of 2½ hr. Each hot-hardness value represents the average of at least four readings on each of triplicate specimens.

A comparison of the data indicates that very similar hot-hardness characteristics are obtained in the 18-4-1 steel (with no molybdenum), the 6-6-4-2 steel (with intermediate tungsten and intermediate molybdenum) and the molybdenum-vanadium steel (with no tungsten). Molybdenum thus seems to be a very effective substitute for tungsten, as far as hot-hardness is concerned, at least up to temperatures of 1100° F., provided that the vanadium and carbon contents are simultaneously increased. The 14-4-2 grade shows up rather well at 1000° F., but is definitely inferior to the above three steels at the higher temperatures. Particularly notable is the beneficial effect of cobalt: The 12% cobalt type exhibits the highest hot-hardness, and the 5% cobalt the next highest. Occupying an intermediate position between the cobalt and the 18-4-1 steels are the 18-4-2 and the high carbon, high vanadium types.

It must be emphasized that the hardness of these steels at elevated temperatures may be profoundly influenced by the degree of carbide solution achieved at the hardening temperature, and consequently the hot-hardness properties of any given steel depend upon the high heat treatment as well as the composition. However, the results in the table are presented as an example of the data obtainable with the equipment under discussion.

*Effect of Tempering Time* — The high sensitivity of this method permits an instructive study of hardness changes during tempering. Curve A in the diagram was obtained by tempering individual specimens of hardened 18-4-1 steel for different times at 1050° F., and cooling to room temperature for the cold-hardness readings. Then the specimens were quickly heated to 1000° F. for hot-hardness testing, to yield Curve B.* It is evident that maximum secondary hardening as measured at room temperature is attained by tempering for less than an hour, but tempering for 2½ hr. is required to produce maximum secondary hardening as measured at 1000° F. Hence, room temperature hardness does not offer an accurate criterion of high temperature hardness, even when dealing with a single steel.

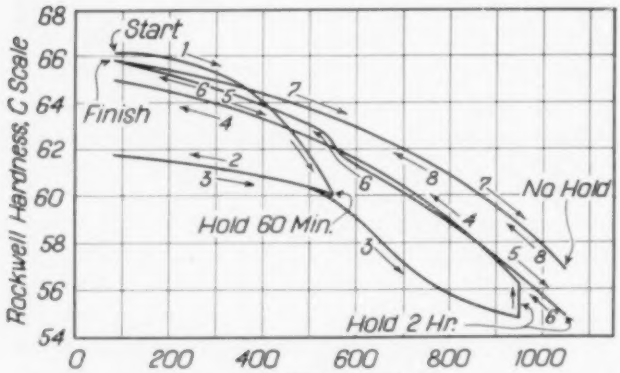



*Changes in Hot-Hardness, Room Temperature Hardness, and Specific Volume (Transformation of Retained Austenite) in 18-4-1 High Speed Steel as a Function of Tempering Time at 1050° F.*

Furthermore, the specific volume (curve C) reaches a maximum after 2½ hr. at 1050° F., and remains substantially constant, thus demonstrating that complete decomposition of the retained austenite occurs simultaneously with maximum hot-hardness, but later than maximum

*The hot-hardness values corresponding to very short tempering times are not given because they cannot be accurately determined, since the tempering continues during the time required for hardness testing at 1000° F.

cold-hardness. It is important to note, therefore, that complete transformation of the retained austenite in high speed steel is desirable, not only to attain dimensional and structural stability, but also to develop the maximum potential hot-hardness consistent with the hardening treatment used. This is the reason that the tempering treatments listed in the table were adjusted to convert all of the retained austenite in the various steels.




*Changes in Hardness of a Quenched Piece of 18-4-1 High Speed Steel During the Following Heatings and Coolings: Curve 1, during heating to 550° F. and holding for 1 hr.; Curve 2, during cooling from 550° F. back to room temperature; Curve 3, during reheating to 950° F. and holding for 2 hr.; Curve 4, during cooling from 950° F. back to room temperature; Curve 5, during reheating to 1050° F. and holding for 2 hr.; Curve 6, during cooling from 1050° F. back to room temperature; Curve 7, during reheating to 1050° F. momentarily; and Curve 8, during cooling from 1050°F.*

## *Changes During Heating and Cooling*

As an illustration of the application of hot-hardness observations to the study of structural changes during the tempering of high speed steel, the hardness variations in quenched 18-4-1 steel were measured during the cycles of operations shown in the caption of the second diagram. By correlating these changes with tempering studies previously published by Cohen and Koh ("The Tempering of High Speed Steel", *Transactions* 1939, p. 1015), a straightforward interpretation becomes possible.

In the as-hardened condition, the 18-4-1 steel contains primary martensite, retained austenite and undissolved carbides. During the initial heating to 550° F. (curve 1), the martensite decomposes, and accounts for the rapid rate of softening between 300 and 550° F. However, not all of this decrease in hardness is attributable to the microstructural change; a part of it is due to the inherent or reversible softening which attends the elevated temperatures at which hardness is measured. The extent of the latter effect is indicated by the cooling curve 2, in which the temperature-dependent hardness is recovered, the cooled specimen measuring C-62 at room temperature. Thus, while the "at temperature" hardness decreases from Rockwell C-66 at room temperature to Rockwell C-60 at 550° F., about four points of this softening are caused by the tempering of the martensite, and only two points are due to temperature dependence.

On reheating this same sample to 950° F., the declining hardness curve 3 exhibits an inflexion above 650° F.; hence, the normal rate of softening due to higher temperature is obviously retarded by the entrée of a second structural change. This hardening effect (superimposed upon the temperature-dependent softening) is caused by the precipitation of carbide from the retained austenite, and is particularly noticeable during the hold at 950° F. On cooling from 950° F. (curve 4), the temperature-dependent hardness is regained by the steel, reaching C-65 at room temperature, so the net hardening associated with the carbide precipitation is about 3 points on the Rockwell C scale.

The uniformity of the cooling curve 4 and the virtual coincidence of the reheating curve 5 demonstrate that no structural hardening occurs during the cooling from the soak at 950° F. However, after holding at 1050° for 2 hr., during which no hardness change is observed, the jog at 550° F. in curve 6 denotes the hardening effect due to the formation of secondary martensite from the retained austenite. Evidently, the retained austenite must be "conditioned" at 1050° F. before it can transform during cooling, even though the bulk of the precipitation hardening takes place during the previous treatment at 950°. It is noteworthy that the hardening caused by the austenite transformation is only about one point on the C scale, or one-fourth of the total secondary hardening as measured at room temperature, the rest being due to the original carbide precipitation. However, subsequent cycles of reheating to and cooling from 1050° F. reveal that the presence of the secondary martensite has materially improved the inherent heat resistance of the steel, because the reversible hardness-temperature curves 7 and 8 have a more gradual slope than the reversible curves 4 and 5 exhibited by the steel after the 950° treatment. For example, while the decomposition of retained austenite results in a one-point improvement in hardness at room temperature, the improvement is two points when the comparison is made at 1050° F. Thus, the secondary martensite actually contributes more hot-hardness to the steel than it does cold-hardness. *(Continued on page 442)*

# Quality Control of Munitions*

THE QUALITY needed in ordnance materiel calls for a degree of perfection in mass production which has been uncommon in the past. Determination of the presence of defects often requires test and inspection procedures which are themselves destructive. In these circumstances, some chances simply must be taken if the field forces are to receive any fighting equipment at all.

But even where the necessary inspections are not destructive, the human factor of "inspection fatigue" steps in to prevent absolute conformance to specification requirements. So 100%, or 200%, or even 500% manual inspections are not the answer where large quantities of material are involved. Mechanical gaging and photo-electric cell gaging are being used wherever possible to circumvent inspection fatigue, but even the best of these substitutes have their own margins of error. The element of risk just can't be eliminated and the real problem is how to reduce the chances which must be taken to a minimum without unduly impeding output. Quality control techniques are therefore built around the principle of limiting such risks to a predetermined degree, and are impossible without properly planned inspection arrangements on a statistically sound sampling basis. Furthermore, statistical quality control will tend to require a smaller amount of testing and inspection.

Actually, quality control can indicate the existence of unfavorable conditions before evidence that difficulties are developing would otherwise become available. It will do this, however, only if it is properly used; that is, if the right factors are watched and if the necessary computations, plotting of inspection results, and other steps can be carried out and conclusions drawn from them accurately and promptly. In general, it requires a tailor-made plan to fit each product and each individual set of production conditions.

The first step determines the quality of the material under normal conditions. This is generally referred to as the "process-average quality". For example, it may be expressed as the normal per cent defective of the product as a whole — as the normal measured diameter of a bullet. Determination of the process

(Continued on page 428)

*From "Quality Control of Munitions; the Modern Ounce of Prevention Applied to Ordnance", by G. D. Edwards, *Army Ordnance*, Vol. XXIII, No. 135, November-December 1942, p. 482.

## Quality Control

(Continued from page 426)

average ordinarily requires inspection, measurement, or test of fairly large and well-distributed samples of the product over a representative time.

The next step requires fixing the "acceptable-quality level". This must be in the same terms as the process average so that direct comparison can be made between the two. A suitable lot-by-lot acceptance inspection plan should then be inaugurated with samples large enough to give a prompt indication if lots begin to depart from the average.

Acceptance of 10 to 30 consecutive lots under such a plan (the number depending on conditions) will ordinarily constitute sufficient evidence of control to justify a substantial reduction in inspection. Reductions in these circumstances commonly run from 60 to 85% — ordinarily by a direct reduction in the size of the sample, by less frequent samples of unreduced size, or by a combination of these methods.

The inspection results from each sample must be recorded and the trend of the process average must be watched continuously. In the particular type of control plan described, rejection of a lot is ordinarily looked upon as sufficient evidence of loss of control to require immediate return to the original lot-by-lot sampling basis.

The quality control inspection plan now in effect on armor plate already has reduced by approximately one-half the total amount of ballistic testing necessary by the Ordnance Department. The saving in plate destroyed by test has been substantial.

Another example of the effective application of quality control in ordnance has been in controlling the weight of the powder charge in small-arms ammunition. This has reduced the frequency of adjusting the weighing machines to a point where each machine is in operation an average of nearly a half hour more each day, with a corresponding increase in output of a more uniform product. Quality control also is being applied in the ballistic testing of armor-piercing shot. With one type of shot, for example, the reduction in rounds fired is 75 to 80%.

Once a manufacturer becomes eligible for reduced inspection, his product is accepted without awaiting the detailed results of inspection as long as such evidence continues — of inestimable value in speeding deliveries.

The responsibility for applying quality control plans is being turned over to inspectors close to the work. This will make it possible to tailor quality-control plans to fit local conditions — a factor essential to success.



# Welded Tank Armor

*(Continued from p. 395)* give good fits against butt straps and faying angles or plates. Flattening such armor cannot be done entirely with a stretcher leveller, and hence brake presses and considerable manual labor are necessary. On the other hand, armor to be welded is flattened to a satisfactory degree by stretcher leveling. A flatness tolerance of $\frac{1}{8}$ in. in 3 ft. is acceptable for manually welded construction. A root gap variation of $\frac{1}{16}$ in. is taken care of by depositing more or less weld metal.

Plate edges for welded construction can be flame cut everywhere except at bolted joints to hold machined parts as components of the hull.

Flame cutting of armor need not be followed by flame softening but welds can be made directly to the cut surface provided all heavy scale is removed by touch-up grinding. The hardness of the weld heat affected zone in armor is not decreased by previous flame softening.

Riveting would require drilling approximately 1000 holes in the hull illustrated in Fig. 1. These holes must be reamed before driving the rivets. The adjoining tabulation shows that 291 man-hours would be saved on a welded hull.

**Comparison of Man-Hours Required to Fabricate**

| Riveted Hull | | Welded Hull | |
|---|---|---|---|
| Operation | Hours | Operation | Hours |
| Drilling butt straps | 104 | Flame cutting plates and edges | 9 |
| Drilling armor plate | 184 | Assembly and fit up | 40 |
| Reaming holes, fit up & assembly | 104 | Arc welding | 150 |
| Riveting | 98 | | |
| Total | 490 | Total | 199 |

## *Field Repair*

Tanks in battle will inevitably be penetrated or will come back to field shops with bent plates. If the joints are made by riveting, it will be difficult to repair them, and at best the repair will be heavy for the protection it provides. Holes in armor made by penetrating projectiles can be filled by welding or by inserting repair plugs without a noticeable increase in weight. Bent plates in a welded hull will be of no concern unless cracks occur, and these can be easily filled by welding, while in riveted construction, cover plates would have to be riveted over the openings to prevent the entrance of small arms projectiles or lead splash.

## Tank Design

*(Continued from page 389)*

He is, however, faced by limits at every turn. He can make his engine more compact, but here he is met with demands such as to install very large air cleaners, without which no engine can operate in the desert, and to put up the horsepower in order to carry heavier armor at greater speed. More horsepower entails a heavier transmission. He must protect the crew, giving them space to operate, and also protect the offensive weapons, ammunition and supplies considered necessary by the military. Much as he might like to evict one of the crew and some of the equipment, he is not allowed to do so.

Every increase in weight means a greater stress on the suspension. Increases in weight come not only from thicker armor, a higher scale of equipment, and the calls for more speed and horsepower, but also from increased length to enable wider obstacles to be crossed, bigger offensive weapons with larger and heavier rounds of ammunition, or increased wireless facilities.

It is all a vicious circle!

The big, long tank of the last war had an unsprung suspension and made a bare 5 miles per hr. Present-day tanks (especially American) are fast — in line with the other wheeled transport in cross-country work. There are two other qualities which desert land ships must possess — reliability and ability to run long distances from their bases. Little time and experience has been available to achieve these essentials; the tank has had (compared to automobiles and trucks) but little service and has existed in but small numbers right up to the start of this war, so that experience has been wanting to bring to perfection very difficult designs operating under most adverse conditions. Small wonder is it then that some types or some features of some types in every contesting army have proved unsatisfactory. It would have been a far greater miracle if there had been no unsatisfactory designs, considering the small amount of running experience available.

Now a word about the gun and the projectile: Generally speaking, the smaller the diameter of the bullet, the sooner it loses its initial velocity, and the lower the range at which it can penetrate armor. Thus, even if we assume practically the same muzzle velocity in each case, the rifle is outranged by the small anti-tank gun and the small anti-tank gun by the big one. Hence in the open spaces of the desert the tank with the bigger gun can hold off at arm's length and

*(Continued on page 436)*

## Tank Design

*(Starts on page 389)*

destroy by penetration a tank armed with a smaller weapon, even if this tank is more heavily armored. Thus to some extent the weight disadvantage of carrying a bigger gun and larger projectiles may be counterbalanced by lighter protective armor.

The question of cast versus rolled plate armor has been vigorously argued. Broadly speaking, the better defense against small projectiles, such as an armor-piercing rifle bullet, lies in a steel with a higher Brinell hardness. Against larger anti-tank and field gun projectiles it is a high Izod impact number that counts. Hence for the earlier light reconnaissance tanks only intended to keep out rifle bullets, plate gave the most satisfactory results, especially as castings would have been very thin and difficult to make. To meet the attack of the heavier anti-tank gun, castings come into their own, as the greater thickness makes the production of castings easier; casting facilitates the contours of the carapace, and eliminates many a difficult joint. American and certain continental foundries with their highly developed technique have exploited this rapid system of construction.

The question of welding versus riveting, too, has come in for considerable controversy. Welding of alloy steels has met with more opposition in England than in other quarters. Ability to weld is a great advantage in the field repair shops, lessening the number of repair parts needed, and speeding the return of a crippled machine to the battle front.

Details of the British-built "Churchill" tank were released for publication after the Dieppe raid, when some of them had to be abandoned to the enemy after serving valiantly as strong points against heavy gunfire. Its body is rectangular, roof flush with the top rack. Above this rises a comparatively small rotating turret carrying a six-pounder gun and co-axial machine gun. This tank was devised to repel invasion, and first considered on June 11, 1940. The first pilot model was running on Dec. 12, 1940, and by autumn of 1941, 400 of them were available for battle. That winter certain modifications were made in armor and track protection to fit them for overseas service, and experience with about 1500 of them in the Middle East and Africa has been very satisfactory.

"Valentine" tanks have been especially useful to the Russians; their tracks are standing up well to the hard ground and extreme winter conditions, and they have taken a worthy part in the 1942-1943 break-through to the Don industrial basin.

# Iron Deposition *

ALTHOUGH iron was electrodeposited over 100 years ago, its present use is limited chiefly to electro-forming and electrorefining. Commercial iron plates have been disappointing but electrolytic iron powder offers some promise.

The metal is cheap and abundant. It dissolves readily as an anode. It can be plated out as a hard and brittle metal (which, by heat treatment, can be rendered soft and malleable), or as a soft and ductile metal which can be hardened by carburizing, cyaniding, or nitriding. It welds readily, can be easily plated upon and, when soft, has superior drawing properties. It is of high purity with unusual magnetic properties.

Ferrous sulphate was the first type of bath found practicable. For faster plating at higher temperatures, many baths based on ferrous chloride are better. The chloride bath can be made more concentrated because the salt is more soluble; it conducts the current better, and higher current densities can be used. However, the sulphate bath does not oxidize as readily.

With either, a conducting salt is added, such as a corresponding alkali or alkaline earth salt. These salts also have secondary effects, such as reducing the ion concentration. For depositing soft and ductile metal, simple bath compositions are recommended.

*Iron Sulphate Bath* contains ferrous sulphate as the salt furnishing the metal, either alone, or with additions of ammonium, magnesium, and sodium sulphates. Ferrous ammonium sulphate seems to be the most used. A concentrated solution containing 350 g. per liter (47 oz. per gal.) of ferrous ammonium sulphate operated at about 7 amp. per sq.dm. (65 amp. per sq.ft.) with a temperature of about 60° C. (140° F.) is recommended. For best results, the bath should be kept fully reduced.

This type of bath is principally used for building up undersized machine parts.

*Ferrous Chloride Baths* frequently have additions of calcium, sodium, and magnesium chlorides. For rapid deposition, use a concentration of 4 to 5N ferrous chloride. Brittle metal can be obtained at lower temperatures, soft deposits at 85° C. (185° F.) or higher. For average working conditions a current density of about 6.5 amp. per sq.dm. (60 amp. per sq.ft.) and a temperature of 90° C. (194° F.) are used. The bath must be kept in

(*Continued on page 440*)

*Abstracted from an article by C. T. Thomas in *Transactions* of the Electrochemical Society, Vol. 80, 1941, page 499.

# Iron Deposition

*(Continued from page 438)*

the ferrous condition and at an acidity of about 0.01N HCl. Good deposits can be obtained at current densities as high as 30 amp. per sq.dm. (280 amp. per sq.ft.) by operating at higher temperatures and acidities.

*Bath Impurities* — Organic impurities cause brittle or cracked deposits. Inorganic contaminants are not harmful, except that the concentration of ferric salt must be kept low.

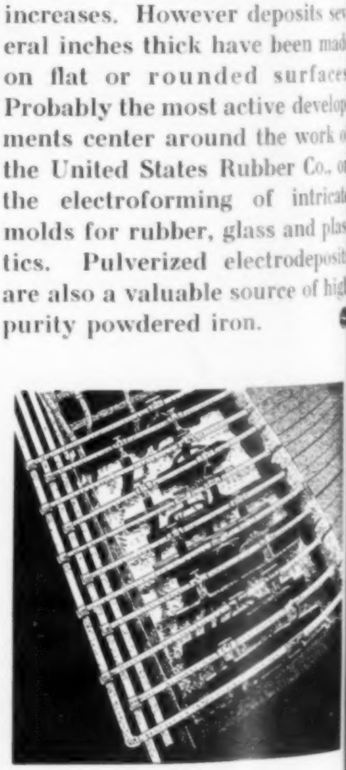
*Anodes* made of high purity iron are preferred. It is usually necessary to bag the anodes.

*Control* — With simple baths regulation of the concentration by specific gravity determinations, with an occasional check analysis for iron, is sufficient.

*Mechanical Properties* depend upon the bath composition and conditions of operation. For the metal as deposited, Kasper reports 127 Brinell hardness for a deposit from a chloride bath made at 10 amp. per sq.dm. at 215° F. Usually the metal is much harder, ranging upward to 360. For a soft deposit Kasper reports a tensile strength of 61,000 psi. and an elongation of 18%, which agrees well with the data of Thomas and Blum. For harder deposits the tensile strength increases to 113,000 psi. with negligible ductility.

After annealing above recrystallization temperature, the mechanical properties approach those of openhearth ingot iron; tensile strength approximates 40,000 psi. with 30 to 40% elongation. The Brinell hardness number drops to 90 or lower after annealing.

*Commercial Possibilities* — While many hopeful experiments in the past have been discouraging, there has always been a persistent interest, which remains strong today. Difficulties in making electroformed tubes and sheets arise from the fact that troubles increase as thickness increases. However deposits several inches thick have been made on flat or rounded surfaces. Probably the most active developments center around the work of the United States Rubber Co., on the electroforming of intricate molds for rubber, glass and plastics. Pulverized electrodeposits are also a valuable source of high purity powdered iron.



## Hot-Hardness

*(Continued from page 416)*

Of course, these data should not be applied too quantitatively to the regular practice of tempering at 1050° F. because of the unorthodox preliminary temperings at 550 and 950° F. These cycles were merely designed to disentangle and emphasize the kinds of hardness phenomena which attend the three important stages that occur in the tempering of high speed steel.

### *Conclusion*

In the light of these typical results, it is evident that the hot-hardness tester described affords an accurate, convenient and useful means of ascertaining the hardness characteristics of hot steel, at least up to 1100° F. Higher testing temperatures may be feasible, but were not attempted. Furthermore, the small impressions produced, the positive control over their location, and the direct readings obtained without disturbing the specimens, make it possible to follow the course of microstructural changes by "at temperature" hardness measurements. Such observations not only help interpret these structural changes but often yield information that is not otherwise obtainable.

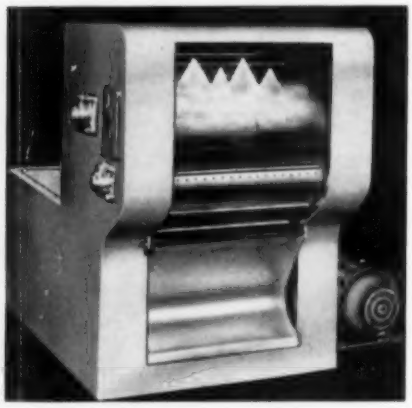
As an illustration, it has been shown that maximum secondary hardness coincides with the complete conversion of the retained austenite in high speed steel, provided the hardness is measured at 1000° F. rather than at room temperature. This is in line with the additional finding that the product of the retained austenite transformation is more effective in enhancing the hot-hardness than it is in enhancing the cold-hardness of the steel.

# New Products

### Metal Washing Machine

A small parts washer, designed around an endless tumbling belt, is a recent development by American Foundry Equipment Co., Mishawaka, Ind.

This batch type machine receives and discharges the parts



to be cleaned through a large front opening. Work is tumbled to expose all surfaces to the cleaning action of the sprays. The open-type barrel gives complete access to the parts while in process, and the spray system is also accessible for cleaning and inspecting the pipes and nozzles.

This "Tumbl-Spray" unit can be heated with steam, gas or electricity, and supplied with full automatic controls.

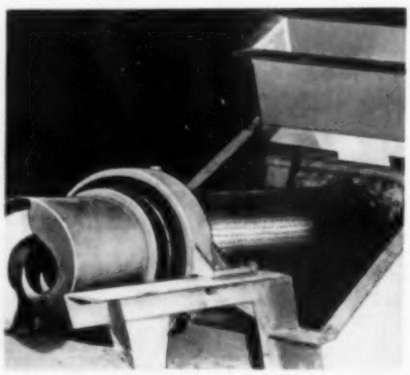
### Powder Metal Press

Automatic press, Model No. 74, is one of the largest machines of its type ever built for producing parts from powdered metals, according to its manufacturer, Kux Machine Co., Chicago. Products such as oil-less bearings, iron gears, metal filters, metallic electrical contact points, small machine parts may be formed on this press from powdered iron, bronze, aluminum, copper or brass. Applying up to 50 tons total pressure, press will produce parts as large as 5 in. diameter and has a powder cell of 5½ in. maximum.

### Spiralveyor

Salem Engineering Co., Salem, O., has developed the "Spiralveyor" to remove large quantities of heat treated parts from the quench. Small stampings or forgings leave the discharge end of a furnace, enter the quench, and can be removed and conveyed to a pickling unit at a rate of 8000 lb. per hr.

The perforated tube drains water from the quench so that



parts enter the pickling solution without diluting it. While the Spiralveyor has been used with heat treating furnaces, Salem's engineers will cooperate with any war production industry which feels this equipment could be applied.

### Resistance Welding Control

Simplified construction is one of the important features of a new electronic capacitor discharge resistance welding control for the resistance welding of aluminum, with its low resistance and high heat conductivity, according to the General Electric Co., Schenectady. This control provides the very high currents and short welding time required for the satisfactory resistance welding of aluminum. Much vital material is eliminated by simplified construction.

### Continental Motors Saves Scarce Metals

Due to the scarcity of alloy steels, methods of welding pieces of scarce metals to bodies of less vital materials are of importance. Continental Motors Corp. now

effects great savings in this way by utilizing scrap high speed steel sections joined to mild steel body. Photograph shows how this company fabricates an unusual cutting tool by chamfering joints in X shape and joining the pieces with "Castolin Eutectic" low temperature welding alloy. A joint is made at 1300° F. with only localized heating, thus preventing the annealing of the heat treated high speed steel, which thus retains all its original hardness. *(More items on page 446)*


ERE'S "MUD IN YOUR EYE" SCHICKLGRUBER!
★ "Mudding" the core for a vital aluminum casting . . . an important operation in speeding the production of Nazi Exterminating Equipment.
The skill and experience of this core and mold finisher, symbolizes the outstanding quality of Nationals' sand and permanent mold aluminum castings.
Good enough is not enough for Uncle Sam. That's why American fighting equipment is the best in the world. National aluminum castings are used in practically all of Uncle Sam's fighting equipment.
So, with slicks* in the hands of experienced men "pasting" and "mudding" cores, it's mud in your eye Schicklgruber.
*Name of tool used in pasting and mudding
TENUAL
ALUMINUM CASTINGS
BUY U. S. WAR BONDS & STAMPS
HE NATIONAL BRONZE & ALUMINUM FOUNDRY CO.
CLEVELAND, OHIO
NEW YO —111 Broadway • CHICAGO—188 W. Randolph • DETROIT—Stephenson Bldg. • LOS ANGELES—405 S. Hill
KERS OF QUALITY SAND AND PERMANENT MOLD ALUMINUM CASTINGS

## New Products

(*Continued from page 444*)

**Straightening Press**

A sensitive, quick acting, shaft straightening press with anvils and centers for testing, is offered by Lake Erie Engineering Corp. of Buffalo. Pumping unit of the press is self-contained in the base of press and provides 20-ton capacity. Ram operates at high speed and is arranged with quick return springs.

**Surface-Angle Plate Inspector**

Device speeds inspection on production operations with controlled accuracy, within tolerances as close as 0.00005, according to Thomas Wilberton & Co., Cedar Grove, N. J. "Surface-Angle Plate", in both benc[h] and floor models, is guarante[ed] within 0.0001 tolerance; with [...] the checking of accuracy on bo[th] surfaces and angles becomes [...] precision operation.



**Cutting Torch**

This new torch, offered b[y] National Cylinder Gas Co., Chi[-] cago, is said to be rugged an[d] fast. It is able to handle, in addi[-] tion to regular plate cutting, suc[h] jobs as hole piercing, cuttin[g] rusty multiple plate, billet de[-] seaming, cast iron cutting, an[d] rivet washing. A new mixin[g]

principle provides a fast preheat[-] ing flame. Oversized passage[s] for high pressure oxygen permi[t] unrestricted flow of the cuttin[g] stream, and mean a fast an[d] economical operation on all meta[l] thicknesses.

**Improves Cutting Tools**

Axel Lundbye, chief enginee[r] of Crowell-Collier Publishing Co., has devised an improvement fo[r] the "doctor blade" on a rotogra[-] vure press, a long, accurate knif[e] that scrapes the excess ink fro[m] printing plates at high speed be[-] fore they are pressed agains[t] paper. The process involve[s] chromium plating and subse[-] quent heat treatment (diffusion) and has proven effective in in[-] creasing the life of simple meta[l] cutting tools. Crowell-Collie[r] Publishing Co. will treat a sam[-] ple cutting tool for any compan[y] making war materials, if a[n] officer of the company will writ[e] Thos. J. Beck, president, 25[0] Park Ave., New York, giving in[-] formation as to the specific us[e] of the tools. If plant tests prov[e] satisfactory, Crowell-Collier wil[l] then furnish the war plant with necessary directions and permis[-] sion to use the technique.

# WHAT'S NEW

## IN MANUFACTURERS' LITERATURE

### METAL WORKING • FABRICATION

*Kennametal tools.* McKenna Metals Co. Bulletin Hf-238.

*"Cylindrical Superfinishing."* International Machine Tool Corp., Foster Div. Bulletin Hf-410.

*Forging presses.* Ajax Mfg. Co. Bulletin Ff-105.

*Horizontal extrusion presses.* Hydropress, Inc. Bulletin Ff-394.

*36-page pictorial story* of the Cecostamp. Chambersburg Engineering Co. Bulletin Ff-132.

*Cutting Oils.* Cities Service Oil Co. Bulletin Ec-113.

*Cutting Oil Handbook.* D. A. Stuart Oil Co. Bulletin Ke-118.

*Presses* for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin Af-335.

*Properties* and uses of cutting oils. Gulf Oil Corp. Bulletin Ef-360.

*Forty different ways* to cut machining costs. Continental Machines, Inc. Bulletin Ef-170.

*Mounted wheels,* Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin Kf-230.

*Savings in oils,* tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin Kf-433.

*Convenient,* pictorial chart shows abrasive cloth gadgets in a form that will guide users in the proper finishing operation. Behr-Manning Corp. Bulletin Nf-467.

*"Hyper-milling"*, a radical innovation in face-milling of steel. Firth-Sterling Steel Co. Bulletin Lf-177.

*Abrasive belt polishing* machines. Divine Brothers Co. Bulletin Kf-434.

*Cutting oils.* Warren Refining & Chemical Co. Bulletin Kf-454.

*Photographs and tables* on operation of abrasive cutting machines. Andrew C. Campbell Div., American Chain & Cable Co. Bulletin Nf-466.

*Newly developed* equipment incorporating use of surface coated abrasive belts for producing faster finishes is described in booklet issued by Minnesota Mining & Mfg. Co. Bulletin Ag-470.

*Illustrated literature* on presses for powder metallurgy. Hydraulic Press Mfg. Co. Bulletin Cg-475.

*New and faster method* of grinding and polishing with abrasive belts is described in booklet issued by Hammond Machinery Builders, Inc. Bulletin Cg-363.

*New 24-page booklet* illustrates high production presses. E. W. Bliss Co. Bulletin Cg-380.

*Illustrated data information* on cutting oils and their correct use in machining operations. National Refining Co. Bulletin Cg-479.

### FERROUS METALS

*New process embodying* both chemical and temperature controls for production of low carbon open hearth case carburizing steel is described in bulletin by W. J. Holliday & Co. Bulletin Bg-293.

*"100 Years of Peace and War"* is title of attractive brochure celebrating 100th birthday of Joseph T. Ryerson & Son, Inc. Bulletin Bg-106.

*Enduro stainless steels.* Republic Steel Corp. Bulletin Hf-8a.

*Hard Facing Alloys.* Wall-Colmonoy Corp. Bulletin Kd-85.

*Free Machining Steels.* Monarch Steel Co. Bulletin Cd-255.

*Tool Steels.* Bethlehem Steel C Bulletin Ce-76.

*Die Steels.* Latrobe Electric Ste Co. Bulletin Ld-208.

*Enameling iron sheets.* Inlan Steel Co. Bulletin Ld-295.

*NAX high tensile low alloy stee* Great Lakes Steel Corp. Bulletin K 229.

*Loose-leaf reference book* on mo lybdenum steels. Climax Molybde num Co. Bulletin Hb-4.

*Four Coppco* tool steels. Coppe weld Steel Co. Bulletin Cf-311.

*Simplified method* for calculatin heat treatment of alloy steels. Pet A. Frasse & Co., Inc. Bulletin Cf-17

*Nitralloy* and the Nitriding Pro ess. Nitralloy Corp. Bulletin Df-11

*Information for determining* over all heat transfer rates. Internation Nickel Co. Bulletin Kf-45.

*Wall Chart* on spark testing to steels. Carpenter Steel Co. Bullet Kf-12.

*Aircraft steels,* bearing steel Rotary Electric Steel Co. Bullet Kf-429.

*Steels.* Boker & Co. Bulletin Kf-45

*Cold drawn steels.* Wyckoff Draw Steel Co. Bulletin Kf-99.

*Steel Data Sheets.* Wheelock, Lov joy & Co. Bulletin Ox-74.

*Saving* of stainless steel throu use of Pluramelt. Allegheny Ludlu Steel Corp. Bulletin Df-92.

*New 60-page data book* on moly denum wrought steels has been i sued by Molybdenum Corp. of Ame ica. Bulletin Nf-312.

*Shop notes* on the machining stainless steels are presented in ne 24-page book by Rustless Iron Steel Corp. Bulletin Nf-169.

*Information* on SuVeneer cl metal. Superior Steel Corp. Bullet Cg-474.

Use Handy Coupon Below for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 450, 452, 454, 456, 45 460, 462 and 464.

**Metal Progress** 7301 Euclid Ave., Cleveland
**Send me the literature I have indicated below.**

Name ........................................Title ........................................

Company ........................................Address ........................................

(Students—please write direct to manufacturers.)

**Check or circle the numbers referring to literature described on these 9 pages.**

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| Ff-394 | Cg-475 | Cf-172 |
| Ff-132 | Cg-363 | Df-116 |
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| Bf-66 | Nd-123 | [illegible] |
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| Ff-321 | Bc-82 | [illegible] |
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| Lb-25 | Ke-260 | [illegible] |
| Na-138 | Hb-81 | [illegible] |
| Kc-34 | Cf-70 | [illegible] |
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| Lf-108 | Cg-477 |
| Lf-460 | |

# MEEHANITE FOUNDRIES SERVE ALL IMPORTANT PRODUCTION CENTERS



# Nation-wide "KNOW HOW" solves your casting problems

No matter where you are, you won't have to go far to get genuine Meehanite castings having engineering properties meeting your specific needs! In all principal manufacturing centers, you will find well-established, modern foundries offering the exclusive advantages of Meehanite Castings.

These selected foundries are members of the Meehanite Research Institute of America, Inc., an organization established to improve foundry practice through scientific research and better manufacturing procedure, and to establish and maintain higher standards of uniform quality and dependability. Through this organization and the headquarters metallurgical staff, cooperative engineering development and research programs far beyond the scope and resources of any private foundry are constantly in progress.

To focus the attention of this broad organization on your individual problems, get in touch with the nearest Meehanite foundry. Through them, the entire engineering and metallurgical resources of the organization are made available to you.

## what is MEEHANITE?

Meehanite is a unique cast metal in which the better properties of both cast iron and steel are combined. In its 21 distinct types, Meehanite offers such properties as: high strength; resistance to heat, wear, corrosion; exceptional machinability; vibration damping; adaptability to flame hardening and heat treatment; uniform adherence to predetermined properties.

**MEEHANITE RESEARCH INSTITUTE**

**311 ROSS STREET · PITTSBURGH, PA.**

# WHAT'S NEW

## IN MANUFACTURERS' LITERATURE

### NON-FERROUS METALS

*Three new bronzes* are described in new Ampco Metal, Inc. Bulletin Bg-175.

*Silver alloy brazing.* Handy & Harman. Bulletin Hf-126.

*Bronze.* Frontier Bronze Corp. Bulletin Kf-455.

*6th edition of Revere Weights* and Data Handbook includes new section giving technical and mill definitions and illustrations of terms used in copper and brass industry. Revere Copper and Brass, Inc. Bulletin Bg-239.

*Copper Alloys.* American Brass Co. Bulletin Kd-89.

*Aluminum alloys* for aircraft. Reynolds Metals Co. Bulletin Lf-436.

*Platinum Metal Catalysts.* Baker Co., Inc. Bulletin Af-337.

*"Machining Alcoa Aluminum"*. Aluminum Co. of America. Bulletin Kf-54.

*Features and savings* incorporated in die casting equipment of Lester Phoenix, Inc. Bulletin Kf-437.

*Cerrosafe*, a low temperature melting metal, used to accurately prove cast cavities. Cerro de Pasco Copper Corp. Bulletin Kf-421.

*Aluminum Castings.* National Bronze & Aluminum Foundry Co. Bulletin De-307.

*Handy, compact reference* data on brass and bronze castings. Hammond Brass Works. Bulletin Df-371.

*Reference* on properties of lead. St. Joseph Lead Co. Bulletin If-41

*Catalog of brass*, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin Gf-67.

*Dowmetal data book.* Dow Chemical Co. Bulletin Ec-215.

*80-page* Duronze Manual, well indexed for reference, presents data on high strength silicon bronze. Bridgeport Brass Co. Bulletin N-163.

*Forgeable tin-free* bearing metal. Mueller Brass Co. Bulletin Cg-481.

*Surface protection* for magnesium. American Magnesium Corp. Bulletin Cg-482.

*Rare metals*, alloys and ores. Foote Mineral Co. Bulletin Cg-483.

*Attractive booklet* on Bunting cast bronze, sleeve type standardized bearings. Bunting Brass & Bronze Co. Bulletin Cg-473.

*Handy, 20-page booklet* is devoted to principal grades of aluminum. Niagara Falls Smelting & Refining Corp. Bulletin Cg-467.

*New pamphlet* covers standard specifications for all grades of aluminum alloys (casting grades only). Federated Metals Div., American Smelting and Refining Co. Bulletin Cg-478.

### WELDING

*Arc Welding.* Lincoln Electric Co. Bulletin Ff-10.

*Welding Stainless.* Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin Ne-86.

*Stud welding* equipment designed for ship deck work but fully meeting requirements of many other uses calling for end-welding of steel sections to metal surfaces is described in new leaflet by Hollup Corp., division of National Cylinder Gas Co. Bulletin Bg-331.

*Chart explains* how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin Ff-393.

*Electrode quantity* and welding time graph. Arcos Corp. Bulletin Ld-191.

*"Fight-waste"* booklet. Air Reduction Sales Co. Bulletin If-69.

**Use Handy Coupon on Page 449 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 448, 452, 454, 456, 458, 460, 462 and 464.**


## "... PARTS, FITTINGS, FORGINGS, CASTINGS--HOLDING UP PRODUCTION"

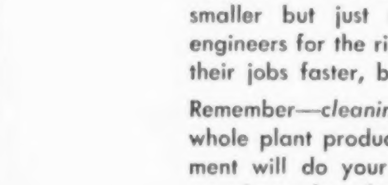
from
*"BOTTLENECKS AGAIN"
Business Week
Issue January 23, 1943

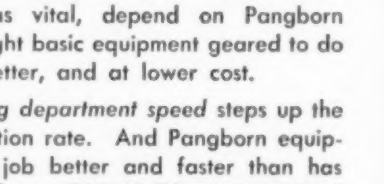
WHY? The miners and ingot producers are delivering the metal. Arms assembly plants are going great guns. But in between—the suppliers—the plants producing parts, fittings, forgings and castings —is where a bottleneck still bogs down production because of S-L-O-W cleaning.

What a different news story if all plants had Pangborn Air or Airless ROTOBLAST for their cleaning room requirements. One war installation is blast cleaning 2,000 five hundred pound steel bombs per day. Hundreds of other concerns, whose orders were smaller but just as vital, depend on Pangborn engineers for the right basic equipment geared to do their jobs faster, better, and at lower cost.

Remember—*cleaning department speed* steps up the whole plant production rate. And Pangborn equipment will do your job better and faster than has ever been done before. "COME TO PANGBORN."

**PANGBORN CORPORATION**
World's Largest Manufacturer of Blast Cleaning and Dust Control Equipment
**HAGERSTOWN : : : : MARYLAND**





**PANGBORN**

# *WHAT'S NEW*

IN MANUFACTURERS' LITERATURE

*Oxy-acetylene welding* and cutting. Linde Air Products Co. Bulletin Ge-63.

*Shield Arc electrodes.* McKay Co. Bulletin Gf-248.

*Sciaky radial portable welder.* Sciaky Brothers. Bulletin Kf-425.

*Castolin Eutectic Alloys* as a substitute for scarce bronze or brass welding rods. Eutectic Welding Alloys Co. Bulletin Lf-301.

*Two-stage "Regolator"* for producing a non-fluctuating welding flame. National Cylinder Gas Co. Bulletin Af-331.

*Speed is increased* 20 to 30% and power costs cut one-third with the Flexarc A-C welders described in new booklet by Westinghouse Electric & Mfg. Co. Bulletin Ag-13[illegible]

*Preheating,* welding and normalizing by electrical reaction and induction is described in leaflet by Electric Arc, Inc. Bulletin Ag-468.

*Arc welding accessories* available through General Electric Co. are illustrated in new Bulletin Lf-60.

*New precision welder* with the streamlined arc is described in leaflet issued by Hercules Electric & Mfg. Co., Inc. Bulletin Nf-470.

*Arc-welding* without preheat in the repair of brass and bronze castings is described in engineering data sheet issued by Ampco Metal, Inc. Bulletin Ag-175.

*"Sureweld"* protected arc electrodes, in many types and sizes, described in illustrated literature. Hollup Corp., division of National Cylinder Gas Co. Bulletin Ag-331.

*Data book facts* on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin Cg-220.

*Welding and brazing* of aluminum, a new data book issued by Aluminum Co. of America. Bulletin Cg-5[illegible]

*Leaflet illustrates* various types of spot, seam, flash, projection and gun welding by Thomson-Gibb Electric Welding Co. Bulletin Cg-375.

## TESTING & CONTROL

*X-ray crystal* analysis apparatus is described and illustrated in new folder by Philips Metalix Corp. Bulletin Bg-471.

*New 29-page catalog* — Micromax Electric Control — has just been issued by Leeds & Northrup Co. Bulletin Bg-46.

*Wheelco Instruments Co.* has just issued five new bulletins describing its complete line of industrial indicating, recording and control thermometers. Bulletin Bg-110.

*"Kodak Products* for Industrial Radiography". Eastman Kodak Co. Bulletin Ff-395.

**Use Handy Coupon on Page 448 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 448, 450, 454, 456, 458, 460, 462 and 464.**

# WHAT'S NEW

## IN MANUFACTURERS' LITERATURE

*Bristol Co.* has issued series of bulletins covering automatic control and recording instruments for industrial furnaces, dryers, kilns and ovens. Bulletin Bg-87.

*Inspection* of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin If-401.

*Industrial radiography* with radium. Canadian Radium & Uranium Corp. Bulletin Ff-320.

*Metallurgical laboratory apparatus.* Burrell Technical Supply Co. Bulletin Ff-213.

*Tension and compression strains.* American Instrument Co. Bulletin Nv-259.

*X-Ray Diffraction Unit.* General Electric X-ray Corp. Bulletin Hc-6.

*Radium for industrial radiography.* Radium Chemical Co., Inc. Bulletin Bf-345.

*Universal enclosed terminal head.* Arklay S. Richards Co. Bulletin Ne-330.

*Film and plate processing* equipment for spectro analysis. Harry W. Dietert Co. Bulletin Af-198.

*Pyrometer Controller.* Illinois Testing Laboratories, Inc. Bulletin Hb-180.

*Optical Aids.* Bausch & Lomb Optical Co. Bulletin Ce-35.

*Universal testing machines* and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin Cf-157.

*Metallographic polishing powder.* Conrad Wolff. Bulletin Cf-368.

*Portable Brinell hardness tester* and folding Brinell microscope. Andrew King. Bulletin Df-377.

*8-page leaflet* makes a detailed presentation of the Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin Lf-7.

*Laboratory and industrial* electric furnaces manufactured by Cooley Electric Mfg. Corp. are described in new Bulletin Lf-462.

*Automatic stress-strain recording* is discussed comprehensively and equipment is pictured in new booklet by Baldwin-Southwark Div., Baldwin Locomotive Works. Bulletin Lf-67.

*Metallurgical Equipment.* Adolph I. Buehler. Bulletin Ke-135.

*Hardness testing equipment.* Wilson Mechanical Instrument Co., Inc. Bulletin Cf-22.

*Modern Polishing.* Tracy C. Jarrett. Bulletin De-303.

*Potentiometer temperature* indicators. Foxboro Co. Bulletin Ef-21.

*Gage blocks,* comparators, projectors. George Scherr Co. Bulletin Kf-206.

*Pyrovac radiation pyrometer.* Bristol Co. Bulletin Kf-87.

*Slomin high speed* electrolytic analyzers and other metallurgical laboratory equipment. E. H. Sargent & Co. Bulletin Kf-458.

*Surface Analyzer.* Brush Development Company. Bulletin Kd-288.

*Polishing Machine.* Cincinnati Electrical Tool Co. Bulletin Ox-97.

*Micro-Optical Pyrometers.* Pyrometer Instrument Co. Bulletin Kc-37.

*X-Ray* metallurgical laboratory service is described and illustrated in new file folder issued by Claud S. Gordon Co. Bulletin Nf-53.

*64-page booklet* on the precision control of industrial processes has been issued by Brown Instrument Co. Bulletin Nf-3.

*Constant temperature* dry-ice cabinet for temperatures from minus 90 deg. to 220 deg. F. is new laboratory instrument described in leaflet by American Instrument Co. Bulletin Ag-259.

*Dillon tensile tester* and the Dillon dynamometer are described and illustrated in new leaflet issued by W. C. Dillon & Co. Bulletin Ag-466.

### HEATING • HEAT TREATMENT

*Tempering, annealing,* stress-relieving. Leeds & Northrup Co. Bulletin Hf-46.

*56-page vest pocket data book* on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin Hf-49.

*24-page catalog* describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin Lf-55.

*Modern electric furnaces* for heat treating are described by Harold E. Trent Co. in new Bulletin Lf-461.

*New 8-page* booklet describes and illustrates gas, oil and electric heat treating and carburizing furnaces of Holcroft & Co. Bulletin Lf-203.

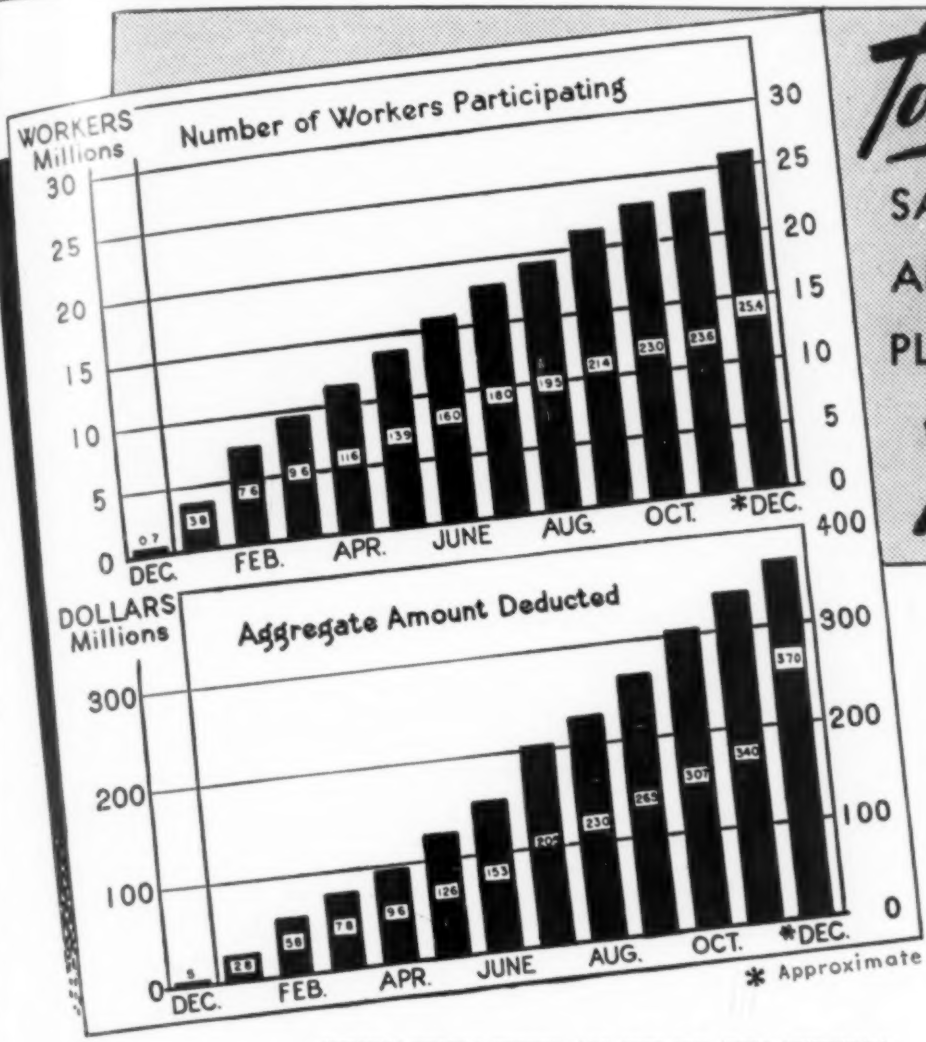
*Faster production* with Tocco hardening, brazing, annealing and heating machines is set forth in new 16-page booklet by Ohio Crankshaft Co. Bulletin Lf-145.

*Kleen-well oil strainers* for quench oil cooling systems is described in leaflet by Bell & Gossett Co. Bulletin Lf-287.

*Gas cracking unit* for production of a protective atmosphere during heat treatment of alloy and high carbon tool steels is described by Hevi Duty Electric Co. in new Bulletin Lf-44.

*Liquid salt baths* for carburizing, annealing, reheating, tempering and neutral hardening are described by E. F. Houghton & Co. in new Bulletin Lf-38.

Use Handy Coupon on Page 448 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 448, 450, 452, 456, 458, 460, 462 and 464.




# *Tomorrow's*

## SALES CURVES ARE BEING PLOTTED . . .

# *Today*

**THESE CHARTS SHOW ESTIMATED PARTICIPATION IN PAYROLL SAVINGS PLANS FOR WAR SAVINGS BONDS** *(Members of Armed Forces Included Starting August 1942)*

STUDY THEM WITH AN EYE TO THE FUTURE!

There is more to these charts than meets the eye. Not seen, but clearly projected into the future, is the sales curve of tomorrow. Here is the thrilling story of over 25,000,000 American workers who are today voluntarily saving close to FOUR AND A HALF BILLION DOLLARS per year in War Bonds through the Payroll Savings Plan.

Think what this money will buy in the way of guns and tanks and planes for Victory today—*and mountains of brand new consumer goods tomorrow.* Remember, too, that War Bond money grows in value every year it is saved, until at maturity it returns $4 for every $3 invested!

*Here indeed is a solid foundation for the peace-time business that will follow victory.* At the same time, it is a real tribute to the voluntary American way of meeting emergencies that has seen us through every crisis in our history.

But there is still more to be done. As our armed forces continue to press the attack in all quarters of the globe, as war costs mount, so must the record of our savings keep pace.

Clearly, on charts like these, tomorrow's Victory —*and tomorrow's sales curves*—are being plotted today by 50,000,000 Americans who now hold WAR BONDS.

EVERYBODY EVERY PAYDAY AT LEAST 10%

*Save with*

# War Savings Bonds

This space is a contribution to America's all-out war effort by

## METAL PROGRESS

# WHAT'S NEW

## IN MANUFACTURERS' LITERATURE

*Unichrome alkaline copper* processes for improvement of selective hardening and deep drawing of steel are described by United Chromium, Inc., in new Bulletin Lf-463.

*Annealing and stress-relieving* of cartridge cases are discussed by Surface Combustion Corp. in new Bulletin Lf-51.

*Method of handling* cylinder anhydrous ammonia for metal treaters is comprehensively described and pictured in 12-page booklet by Armour Ammonia Works, division of Armour and Co. Bulletin Lf-443.

*"Pulverized Coal, the Victory Fuel".* Amsler-Morton Co. Bulletin Ff-286.

*Heat treating furnaces.* Johnston Mfg. Co. Bulletin Ff-155.

*Heat treating production.* Lindberg Engineering Co. Bulletin Bf-66.

*Rotary Hearth Furnaces.* Lee Wilson Sales Corp. Bulletin Ce-302.

*Industrial furnaces,* equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin Ff-321.

*Industrial ovens,* rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin Bf-183.

*Non-metallic Electric* Heating Elements. Globar Div., Carborundum Co. Bulletin Lb-25.

*Low pressure oil burners.* North American Mfg. Co. Bulletin Na-138.

*Industrial Furnaces.* W. S. Rockwell Co. Bulletin Kc-34.

*Certain Curtain Furnaces.* C. I. Hayes, Inc. Bulletin Nc-15.

*Heat treatment* in electric salt bath furnaces. Ajax Electric Co., Inc. Bulletin If-43.

*Modern Shell Furnaces.* Mahr Manufacturing Co. Bulletin Bf-5.

*Butterfly Valves.* R-S Products Corp. Bulletin Bf-234.

*Molten Salt Baths.* E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin If-413.

*Vertical Furnace.* Sentry Co. Bulletin Ne-114.

*Conveyor Furnaces.* Electric Furnace Co. Bulletin Be-30.

*Industrial Carburetors.* C. M. Kemp Mfg. Co. Bulletin Ce-219.

*Convected Air Furnace.* Despatch Oven Co. Bulletin Nd-123.

*New Electric Furnace.* American Electric Furnace Co. Bulletin Gd-2.

*Furnace Experience.* Flinn & Dreffein Co. Bulletin Bc-82.

*Dehumidifier.* Pittsburgh Lectrodryer Corp. Bulletin Bb-187.

*Furnaces.* Dempsey Industrial Furnace Corp. Bulletin Ke-260.

*High Temperature Fans.* Michiana Products Corp. Bulletin Hb-81.

*Turbo-compressors.* Spencer Turbine Co. Bulletin Cf-70.

*Drycolene.* General Electric furnace atmosphere. Bulletin Df-60.

*Electric Furnaces* for laboratory and production heat treatment. Hoskins Manufacturing Co. Bulletin Cf-24.

*Control* of temperatures of quenching baths. Niagara Blower Co. Bulletin Cf-367.

*Electric box type* and muffle furnaces. H. O. Swoboda, Inc. Bulletin Ef-379.

*Lithco,* the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin Ef-319.

*Dual-Action quenching oil.* Gulf Oil Co. Bulletin Df-360.

*Internally heated salt bath furnaces* and pots. Upton Electric Furnace Div. Bulletin Ef-386.

*Induction heating.* Induction Heating Corp. Bulletin Ef-323.

*Sub-zero equipment* for aluminum storage, shrinking of metal parts. Kold-Hold Mfg. Co. Bulletin Kf-399.

*8-page* pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin Nf-154.

*Electric Furnaces.* Ajax Electrothermic Corp. Bulletin He-41.

*S.F.E. Standard Industrial* furnace catalog. Standard Fuel Engineering Co. Bulletin Kf-388.

*New Heat Source,* for Heat Treating, Brazing and Melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin Kc-211.

*New manual* shows many new technical advances — features exclusive, easy-selection charts on gas-burning equipment. National Machine Works. Bulletin Ag-310.

*Flame-type* mouth and taper annealing machine for steel cartridge cases is described in new leaflet by Morrison Engineering Corp. Bulletin Nf-305.

*No-Carb,* a liquid paint for prevention of carburization or decarburization, is described and use illustrated in new leaflet by Park Chemical Co. Bulletin Nf-141.

*16-page* engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin Nf-181.

*Pictorial bulletin* describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin Ag-448.

*Attractive 16-page* illustrated catalog describes furnaces for heat treating ferrous and non-ferrous metals. Despatch Oven Co. Bulletin Ag-123.

*War production* with standard rated heat treating furnaces is pictured in new bulletin by Surface Combustion. Bulletin Ag-51.

**Use Handy Coupon on Page 448 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 448, 450, 452, 454, 458, 460, 462 and 464.**

# *WHAT'S NEW*

## IN MANUFACTURERS' LITERATURE

*Low temperature equipment* for aging, shrinking, etc. Deepfreeze Div., Motor Products Corp. Bulletin Kf-444.

*Heat treating furnaces.* McCann Furnace Co. Bulletin Kf-446.

*Controlled atmosphere furnace* for heat treatment of tool and alloy steels. Delaware Tool Steel Corp. Bulletin Kf-439.

*Furnaces.* Tate-Jones Co. Bulletin Kf-447.



*Gas-burning equipment.* National Machine Works. Bulletin Fe-310.

*Furnaces.* Vulcan Corp. Bulletin Kf-448.

*Interesting and helpful* information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin Cg-484.

*Gas-air premix machine* is described and illustrated in new bulletin by Eclipse Fuel Engineering Co. Bulletin Cg-226.

*Two new bulletins* on vertical carburizers and on carbonia finish, issued by American Gas Furnace Co. Bulletin Cg-11.

*Hagan rotary forging furnaces* are described and illustrated in a new bulletin just issued by George J. Hagan Co. Bulletin Cg-476.

### REFRACTORIES & INSULATION

*Insulating firebrick.* Babcock & Wilcox Co. Bulletin Ce-75.

*Heavy Duty Refractories.* Norton Co. Bulletin Ie-88.

*Super Refractories* catalog. Carborundum Co. Bulletin Ld-57.

*P. B. Sillimanite refractories.* Chas. Taylor Sons Co. Bulletin Ef-218.

*Conductivity* and heat transfer charts. Johns-Manville. Bulletin Df-100.

*Savings* in construction time, labor and money with use of the all Ramix bottom for basic open hearth furnaces are shown in new leaflet by Basic Refractories, Inc. Bulletin Nf-192.

*Brickseal* refractory coating and discussion of why furnace walls break down are presented by Brickseal Refractory Co. Bulletin Ag-469.

### FINISHING, PLATING, CLEANING

*Nielco Laboratories* offers technical data sheet on brass and copper alkali cleaner. Bulletin Bg-472.

*Technical and engineering data* on Tygon and typical uses, such as tank linings, are presented by United States Stoneware Co. in new Bulletin Lf-356.

*Detrex metal cleaning machines*, metal cleaning chemicals and processing equipment are attractively described in new 24-page catalog by Detroit Rex Products Co. Bulletin Lf-111.

*Airless Rotoblast.* Pangborn Corp. Bulletin Hf-68.


Use Handy Coupon on Page 448 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 448, 450, 452, 454, 456, 460, 462 and 464.

## *WHAT'S NEW*

**IN MANUFACTURERS' LITERATURE**

*A protective, deep black finish* to steel. Heatbath Corp. Bulletin H[illegible] 189.

*Alvey Ferguson Co.* shows how various product washing problems were solved. Bulletin Ne-329.

*Pickling.* Wm. M. Parkin Co. Bulletin Ff-193.

*Modern Pickling.* The Enthone Co. Bulletin Ff-240.

*Cadmium Plating.* E. I. duPont deNemours & Co., Inc. Bulletin H[illegible] 29.

*Anodizing and plating equipment.* Lasalco, Inc. Bulletin Kf-457.

*"Indium and Indium Plating".* Indium Corp. of America. Bulletin Df-376.

*Degreasers.* Phillips Manufacturing Co. Bulletin Nc-254.

*Electrochemical Descaling.* Bullard-Dunn Process Div., Bullard Co. Bulletin Ge-143.

*Jetal process* and its characteristics as a protective coating. Alrose Chemical Co. Bulletin Gf-256.

*Tumbling and cleaning.* Globe Stamping and Machine Co. Bulletin Kf-456.

*Motor-Generators* for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin Bf-352.

*Comprehensive new booklet* describes the rust inhibiting wax coatings for protection of metal against rust and corrosion developed by S. C. Johnson & Son, Inc. Bulletin Kf-426.

*Rust Preventative.* Alox Corp. Bulletin Nb-212.

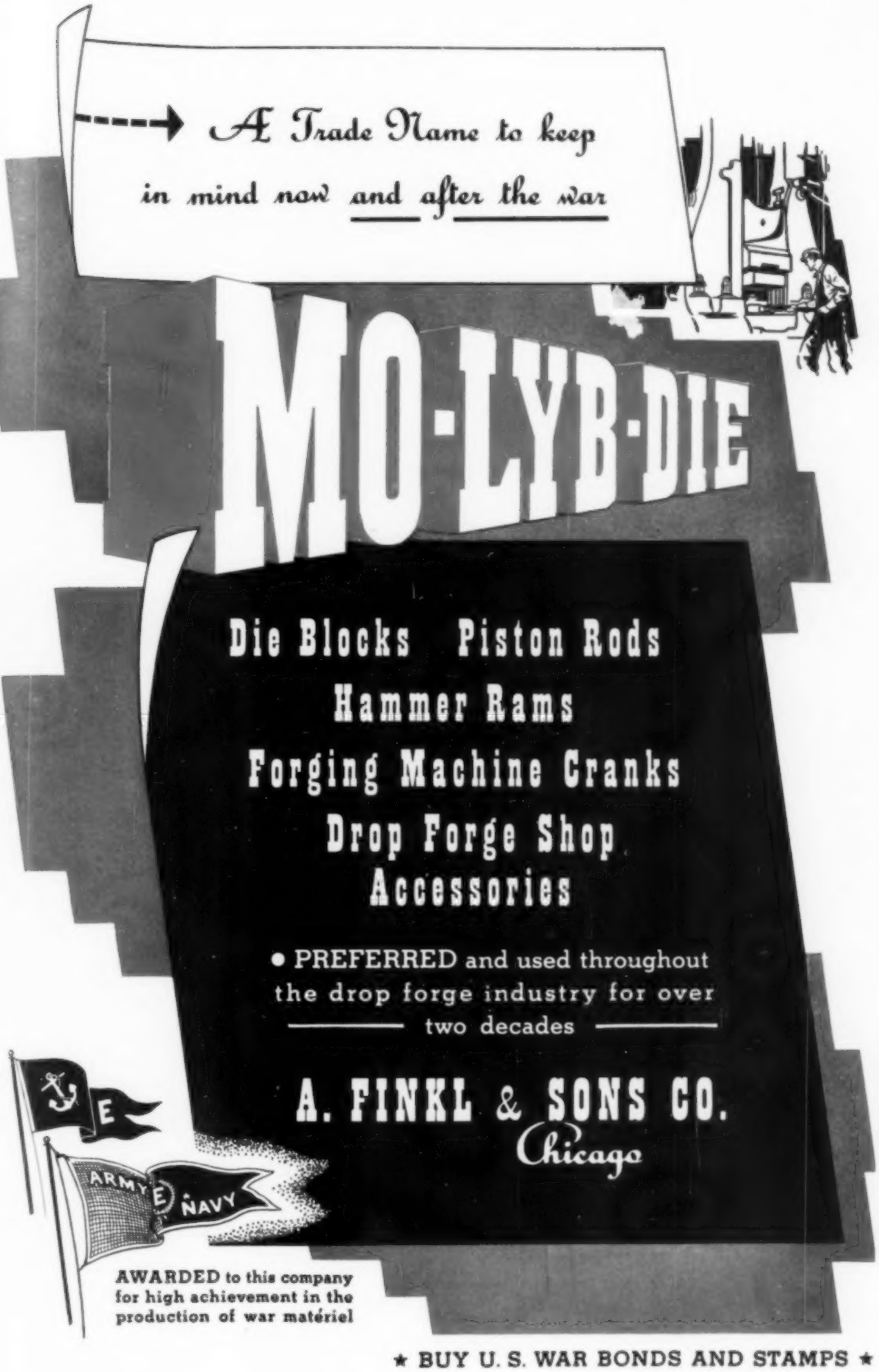
*Casting cleaning methods* in foundries. N. Ransohoff, Inc. Bulletin E[illegible] 381.

*24-page booklet* describes steam-detergent cleaning. Oakite Products, Inc. Bulletin Cg-296.

### MELTING • CASTING • MILL OPERATIONS

*Melting,* holding and alloying furnaces are pictured and described in new booklet by Fisher Furnace Co. Bulletin Bg-195.

Use Handy Coupon on Page 448 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 448, 450, 452, 454, 456, 458, 462 and 464


A Trade Name to keep
in mind now and after the war
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Hammer Rams
Forging Machine Cranks
Drop Forge Shop
Accessories
• PREFERRED and used throughout
the drop forge industry for over
two decades
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*Lectromelt Furnaces.* Pittsburgh Lectromelt Furnace Corp. Bulletin Db-18.



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*New pocket size handbook* present compositions and physical propertie of most commonly used alloy Niagara Falls Smelting and Refinin Corp. Bulletin Bg-467.

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*Electric Furnaces.* Detroit Electri Furnace Div., Kuhlman Electric Co Bulletin Hd-271.

*Chrom-X* for steel mill and found ry. Chromium Mining & Smeltin Co. Bulletin Kf-451.

*Desulphurizer* for molten iron Columbia Chemical Div., Pittsburg Plate Glass Co. Bulletin Cg-480.

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*X-Ray Inspected Castings.* Electr Alloys Co. Bulletin Ld-32.

*Meehanite Castings.* Meehanite Re search Institute. Bulletin Bf-165.

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*Metal Baskets.* W. S. Tyler Co Bulletin Bf-359.

*Steel Castings.* Chicago Steel Foun dry Co. Bulletin He-184.

*Heat Resisting Alloys.* General Al loys Co. Bulletin D-17.

*Pipes and Tubes.* Michigan Stee Casting Co. Bulletin Bb-84.

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*Bimetals* and Electrical Contacts The H. A. Wilson Company. Bulletin Cf-370.

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*Corrosion and heat resistant alloy* Lebanon Steel Foundry. Bulletin El-387.

*Lead-base metals.* Magnolia Metal Co. Bulletin Kf-422.


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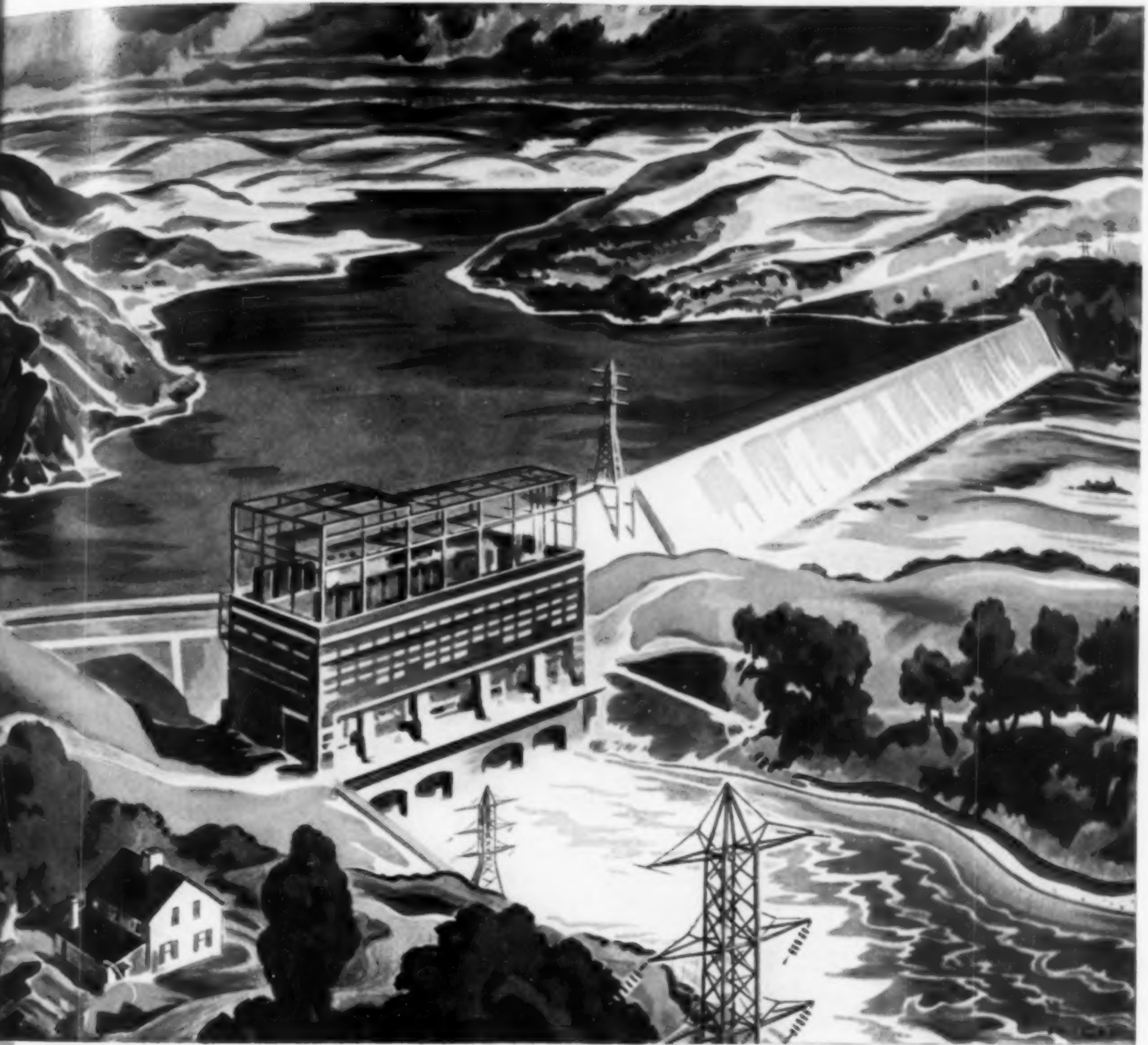

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*Seamless pressed steel* heat treat ing containers. Eclipse Fuel Engi neering Co. Bulletin Ag-226.

*New 48-page catalog* describe place of manganese steel, an answers many questions. America Manganese Steel Div., America Brake Shoe & Foundry Co. Bulleti Cg-9.

*32-page booklet* describes and il lustrates electrical contacts. Fan steel Metallurgical Corp. Bulleti Cg-477.

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